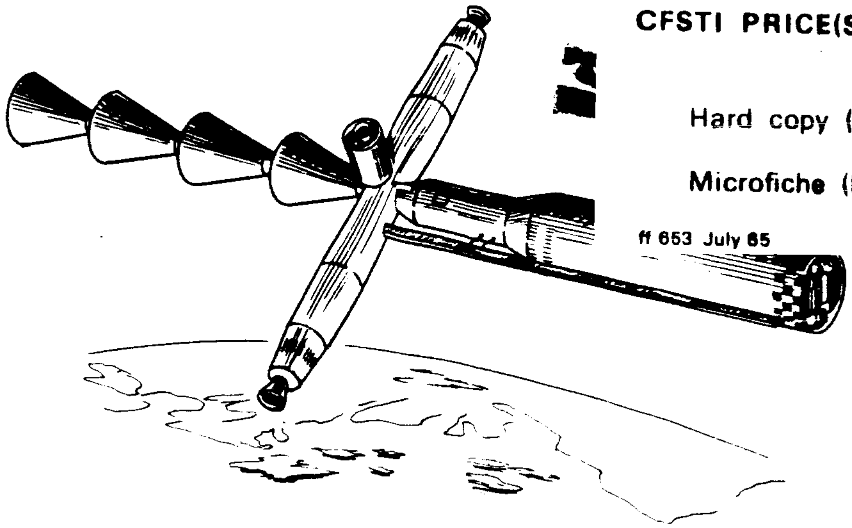
ORBITAL LAUNCH FACILITY STUDY

CONTRACT NO. NAS 8-11355

D2-82559-1 VOLUME I

OLF STUDY TECHNICAL REPORT SUMMARY



PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

THE BOEING COMPANY AERO-SPACE DIVISION
SEATTLE, WASHINGTON

OLF STUDY TECHNICAL REPORT SUMMARY

FINAL REPORT

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This document is Volume I, OLF Study Technical Report Summary, of the final technical report of the Orbiting Launch Facility (OLF) study conducted by The Boeing Company for the Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Alabama, under Contract NAS 8-11355. The study was conducted under the technical supervision of Mr. William T. Carey, Jr.

The final technical report consists of four volumes:

- Volume I: OLF Study Technical Report Summary
- Volume IIA: OLF Study Technical Report (Sections 1 through 4)
- Volume IIB: OLF Study Technical Report (Sections 5 through 7)
- Volume III: OLF Study Research and Technology Implications Report

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TECHNICAL SUMMARY REPORT

1.0 INTRODUCTION

The Orbital Launch Facility (OLF) study, performed for the Marshall Space Flight Center of the National Aeronautics and Space Agency under contract NAS 8-11355, is part of their overall investigation of possible orbital launch operations (OLO). Two other contractors engaged in this overall investigation, Lockheed Missiles and Space Company and Ling-Temco-Vought, studied space checkout and launch equipment (SCALE) requirements and integrated mission requirements of advanced orbital launch operations (AOLO) respectively. The three contracts together made up what NASA referred to as the OLO package. Data was mutually exchanged between the associated contractors to provide an integrated study and a comprehensive evaluation of the entire orbital launch operations.

This volume of the OLF study final report briefly summarizes background material associated with orbital-launch operations applications, specifically that lead into a permanent-facility mode of orbital launch operations, and briefly describes the OLF study, its approach, results, and conclusions.

2.0 ORBITAL LAUNCH OPERATIONS (OLO)

Orbital launch operations, which will be referred to frequently in this report as OLO, are defined for this study as the operations involved in preparing a manned interplanetary or lunar ferry vehicle, in orbit, for its intended mission and performing the actual orbital launch. An orbital launch is only one of several possible methods of accomplishing the initial phase of such missions. The following paragraphs of this section briefly describe several space exploration missions, presently being contemplated, and a number of methods of supporting them.

<u>2.1 Candidate Missions</u>. - As the climax of the initial manned lunar-landing mission draws nearer, increased consideration must be given to follow-on programs in the manned exploration of space. The prospective missions presently being studied include a Mars or Venus flyby mission, a Mars landing mission, and lunar ferry missions for sustaining a lunar base (see Figure 2.1-1).

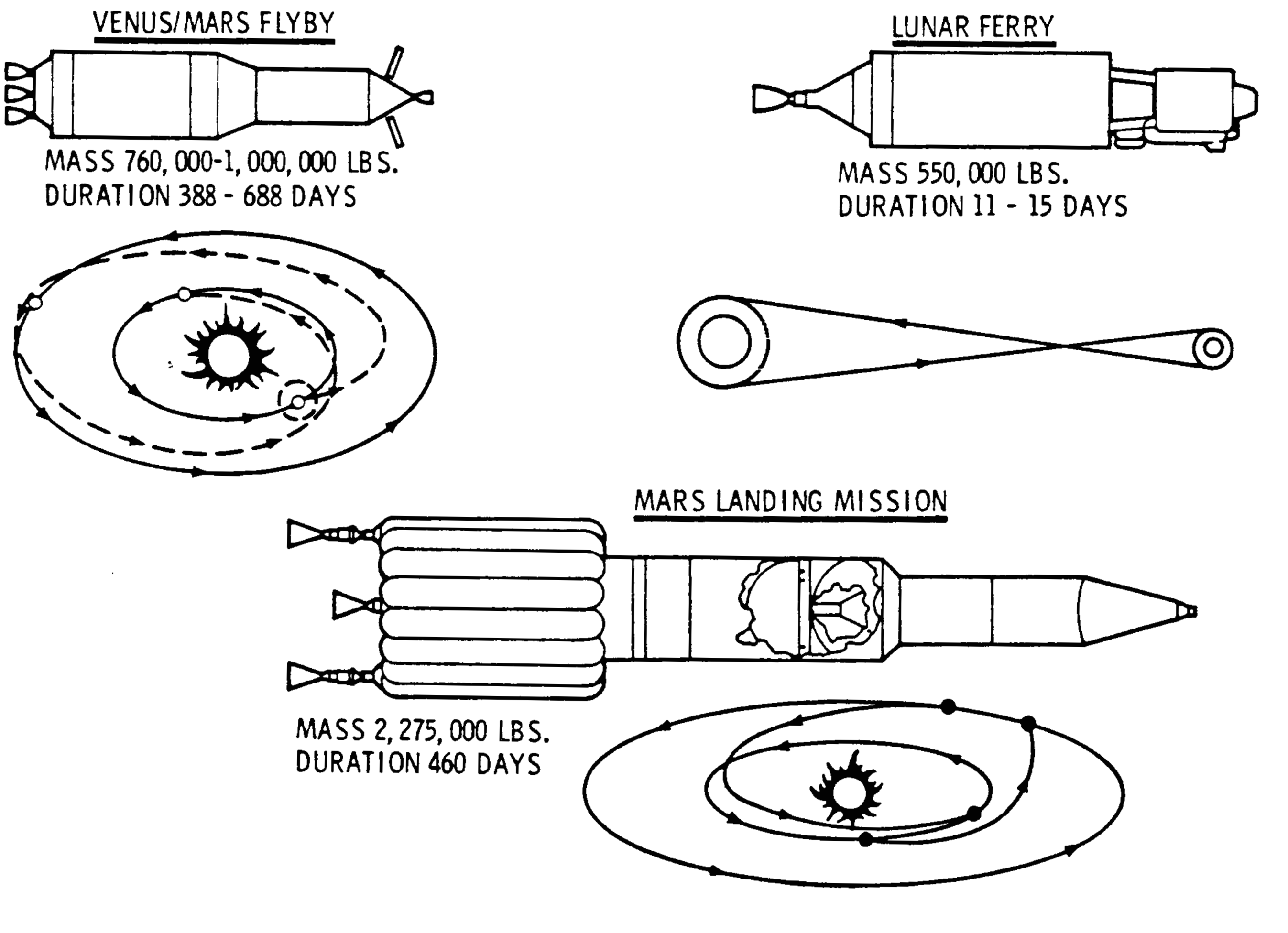


Figure 2.1-1

2.1.1 Mars/Venus Flyby Missions. - This mission is typified by a single major propulsive operation that injects the spacecraft into a trajectory that intercepts the target-planet's orbital path and is timed for a close encounter with the planet. A typical vehicle, designed to accomplish this mission in the 1975 to 1978 time period, carries three men and employs chemical propulsion. Mission duration is approximately 388 days for a Venus flyby and 688 days for a Mars flyby. The Mars/Venus flyby mission, with an earliest launch date postulated for 1975, was designated by NASA as a baseline mission for the initial OLF study.

2.1.2 Mars Landing Mission - This mission requires numerous propulsion maneuvers for injection into the interplanetary trajectory, target planet capture, descent to planet surface and ascent, planet escape, Earth capture, and possibly reentry braking. Chemical, nuclear, and nuclear-electric propulsion systems have been studied for these applications. Such a mission may involve a crew of six men, allow a planet exploration period of about 20 days and require about 460 days total mission time. Study target date for the landing mission was 1983.

2.1.3 Lunar Ferry Mission. - One of the most practical means of performing the lunar ferry mission is use of a reusable nuclear heat-exchanger rocket propulsion system. This mission involves the interorbital transportation of large quantities of cargo, and up to 30 men at a time, between Earth and Moon. Mission durations range from 11 to 15 days. Target date for this mission is 1980.

2.2 Possible Mission Methods. - Exploratory missions described in paragraph 2.1 require systems of ever-increasing size and complexity. The high costs and advanced technology required to execute these missions make it mandatory to consider various possible methods and select one that optimizes such factors as probability of mission success, cost, and crew safety. Several methods considered are described below.

2.2.1 Direct Launch. - A single Earth-launch vehicle is used to boost the mission vehicle directly into the mission trajectory. This method is severely demanding on the Earth launch systems in that the increasingly ambitious missions require large booster payloads. Even for the relatively simple manned Mars or Venus missions payloads in the range of a million pounds or more are required in parking orbit prior to injection into the planetary trajectory. Earth launch vehicles, much larger than those presently under development, would be needed for missions using this method.

2.2.2 In-Transit Rendezvous. - Multiple Earth launches are used to boost major assemblies of the mission vehicle into the mission trajectory. All of the necessary support operations are performed en route. Although this method does allow the use of planned boosters for a vast number of future missions, the complexities of multiple enroute rendezvous and the decreased probabilities of successful abort in case of emergencies makes this method less intriguing. This method, like the direct-launch method previously described, also penalizes the mission systems with added service and maintenance equipment, or overloaded redundancy, to provide the desired probability of mission success.

2.2.3 Target Planet Orbital Rendezvous. - This method--which uses multiple Earth launches, similar to the in-transit-rendezvous method, to boost major assemblies of the mission vehicle from the Earth--has support operations accomplished in an orbit about the target planet. Although this method allows use of booster hardware presently in development, it has poor abort capability and requires systems redundancy or maintenance and servicing penalties to achieve the desired probability of mission success.

2.2.4 Orbital Launch Operations. - Multiple Earth launches boost major mission vehicle assemblies into Earth orbit, where the mission vehicle is assembled, serviced, maintained or repaired, fueled with propellant, checked out, and finally launched. A much broader spectrum of Earth launch vehicles can be used in support of this method and good probability of success is expected in the rendezvous, docking, and possible abort operations in Earth orbit. Also the total probability of mission success can be enhanced by using orbital maintenance, repair, checkout following the boost from Earth, and prior to being committed to the interplanetary transfer, without burdening the mission vehicle with this capability.

2.3 Basic OLO Modes. - Of the various mission methods described above, the orbital launch operations method aroused particular interest and was of prime interest in this study. Three basically different support modes (Figure 2.3-1)

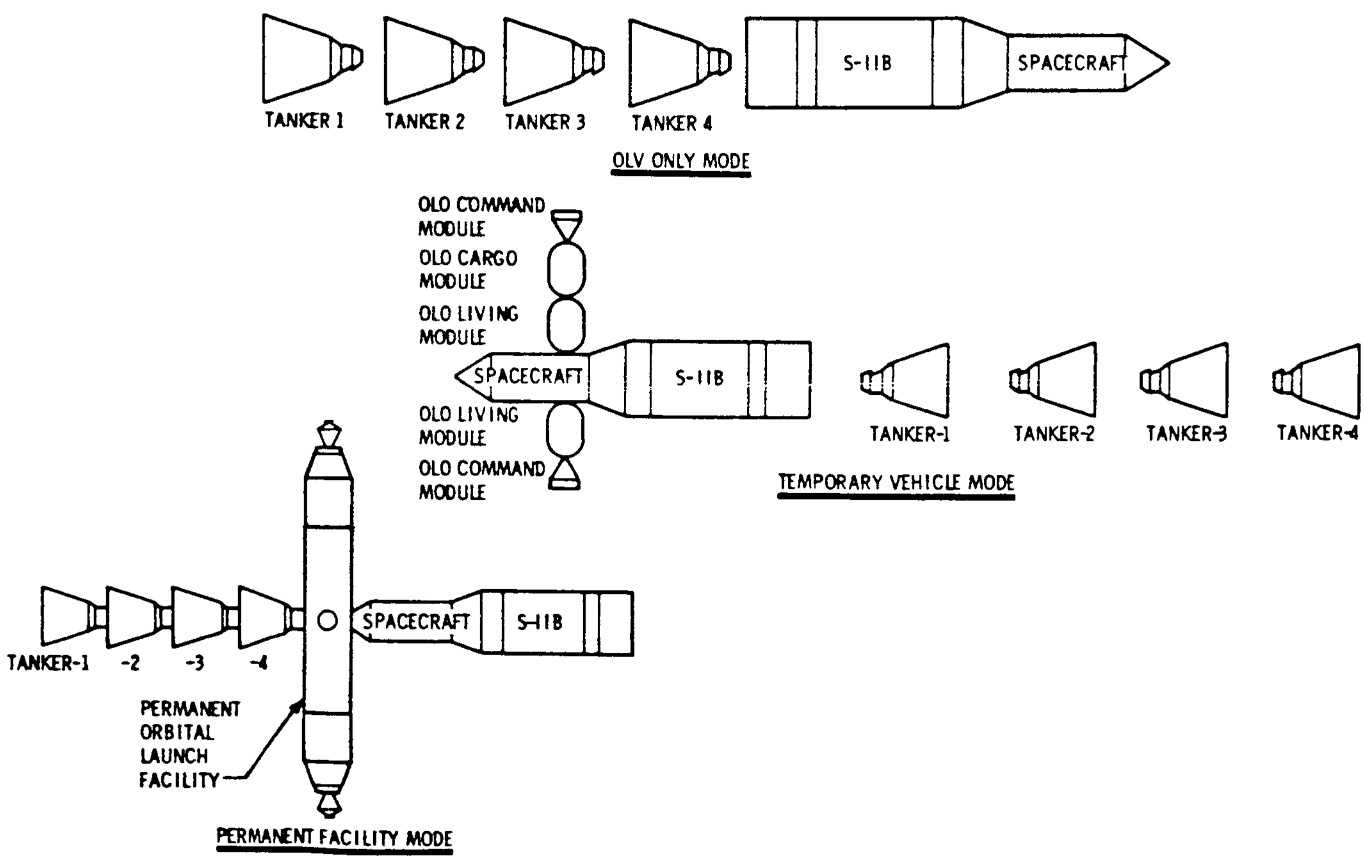


Figure 2.3-1

proposed for this method of operation differ mainly in the manner in which the orbital support is provided and the extent of that support.

2.3.1 Orbital-Launch-Vehicle-Only Mode. - This mode requires only those Earth launches necessary to put the orbital launch vehicle (OLV) assemblies, the servicing tankers, and mission crew into orbit. The OLV consists of the mission spacecraft and the orbital booster. This mode, because of the small orbital crew (the mission crew) and mission payload limitations, has limited maintenance and repair capability. Most of the operations must be automated, thereby adding to the systems complexity and penalizing the total probability of mission success. In this mode the crew must remain in space the entire duration of both the orbital operations and the mission, thus extending the radiation exposure time of the crew.

2.3.2 Temporary Vehicle Mode. - This mode, in which support equipment and manpower is temporarily placed into orbit, provides greater capability for correcting failures in the mission vehicle prior to the orbital launch. Because no penalty is imposed on the mission vehicle or the crew for orbital operations, their design, training, and use can be optimized for the mission. The mission crew can also be boosted into orbit just prior to the mission launch, thereby reducing the total radiation exposure time of the crew.

2.3.3 Permanent Facility Mode. - In this mode support equipment to expeditiously support the orbital launch is permanently housed in orbit. This mode not only has all of the advantages of the temporary vehicle mode but also reduces the strain on Earth-launch facilities in having to launch as many vehicles in such a short time as may be required by the temporary-vehicle mode. The permanent facility also provides an orbital station for other orbital activities and research.

2.4 Baseline OLO Mode. - The object of this study was not to compare the various possible support modes but to evaluate one particular choice--the permanent facility mode--from the standpoint of the basic orbiting-facility's design, development, operation, and maintenance requirements and determine the practicality and technical feasibility of performing a mission such as the Mars/Venus flyby mission. The basic orbital launch operations systems of the permanent-facility mode are briefly described below.

2.4.1 Systems. - The primary systems involved in the permanent-facility mode of orbital launch operations are the orbital launch vehicle (OLV), the orbital launch facility (OLF), Liquid-oxygen tankers, and the logistics spacecraft. (See Figure 2.4-1). The Mars/Venus flyby mission vehicle, here referred to as the OLV, is composed of the spacecraft and a modified S-II stage used as an orbital boost stage (S-IIB). This mission vehicle is the system described in NASA-MSFC's "Manned Planetary Reconnaissance Mission Study: Venus/Mars Flyby" of Reference 1. The OLF shown in the figure is the recommended configuration discussed in Section 4.0. The liquid-oxygen tanker, of which four are used in this mode of operation, is the Lockheed-Saturn V cryogenic tanker configuration (from their orbital tanker study of Reference 2). The Apollo logistics spacecraft assumed for this study is the configuration shown in the Douglas MORL study of Reference 3.

2.4.2 Operations. - The sequence of orbital launch operations in this study is shown in Figure 2.4-2. The first step is the Earth launch and injection into

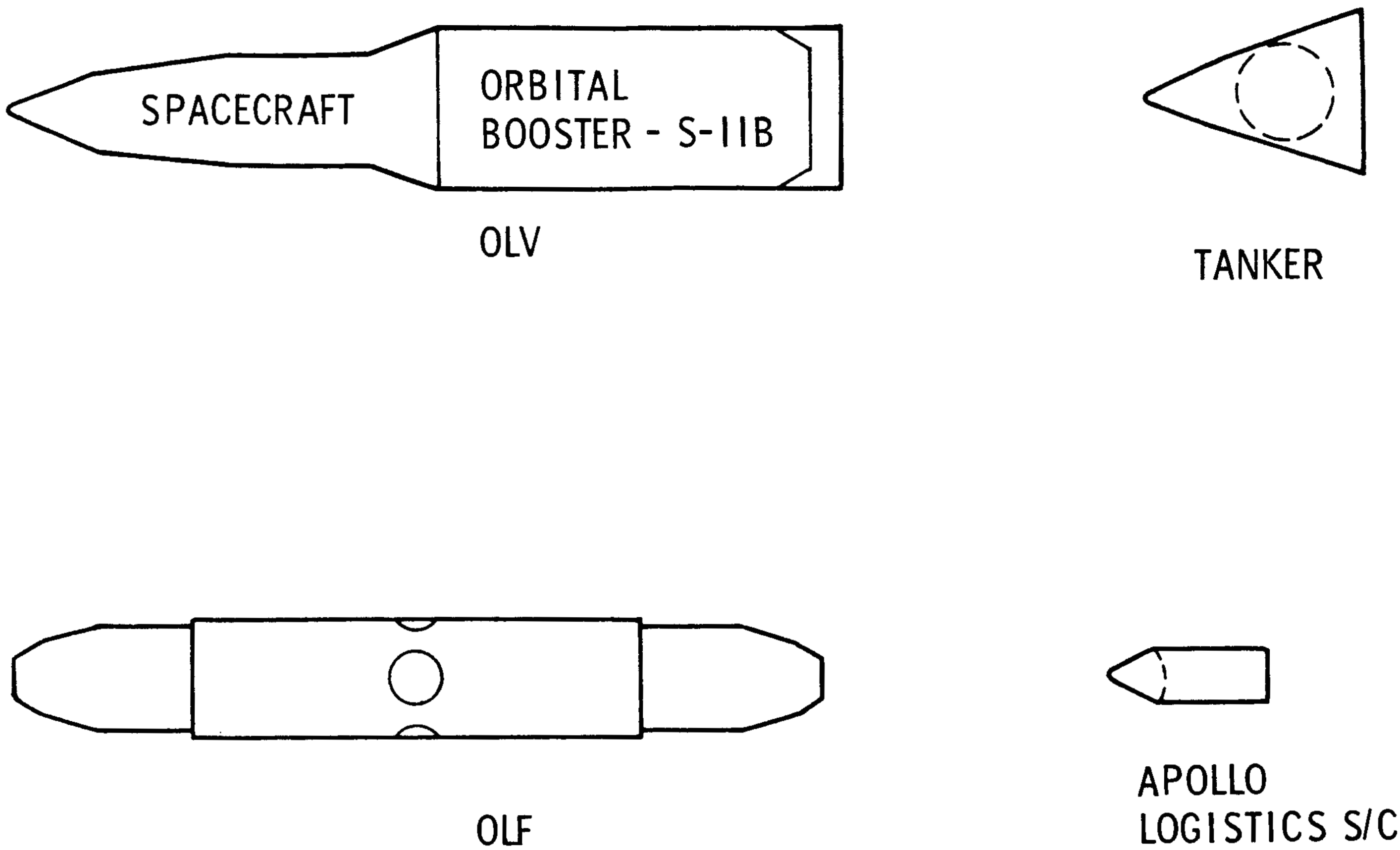


Figure 2.4-1

orbit of the OLF, with subsequent assembly, activation, and checkout of the OLF systems. The completely equipped OLF with a crew of five is launched by a single Saturn V booster. Following verification of the OLF's operability, the spacecraft portion of the OLV is launched from Earth, rendezvoused with the OLF, and hard-docked. The spacecraft is checked out and operability assured. Four LOX tankers, required to provide the full complement of oxidizer, are individually launched, each following the docking and checkout of the previous tanker. The first tanker in orbit is docked directly into the OLF at the docking port opposite the OLV spacecraft. Each subsequent tanker is docked into the aft end of the preceding tanker. Inasmuch as the OLV S-IIB stage is launched with its full hydrogen load, it is limited to about 72 hours in orbit before excessive boil-off occurs; hence, it is necessary to have the entire supply of liquid oxygen in orbit and ready for transfer prior to the Earth launch of the OLV's S-IIB stage. Logistics spacecraft deliver cargo and additional personnel, including the mission crew, to the OLF during the operations. When all of the orbiting systems are in ready condition, the OLV S-IIB stage is launched from the ground, rendezvoused with the OLF, inspected, and finally mated with the OLV spacecraft and checked out. Liquid oxygen is then transferred from the tankers to the S-IIB stage through the umbilical boom provided on the OLF. Following the final check-

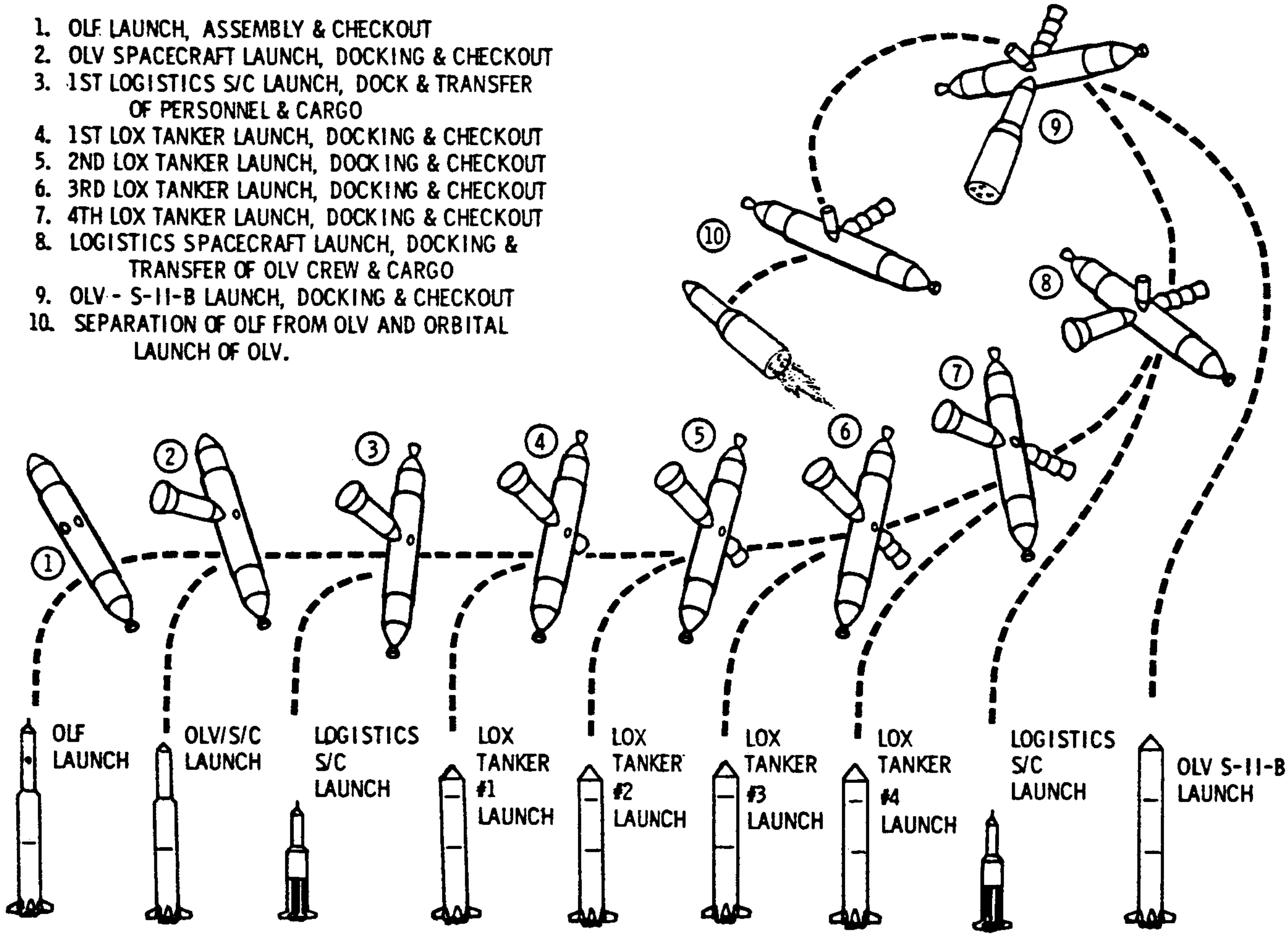


Figure 2.4-2

out and countdown of the OLV with the OLV crew on board the spacecraft, the OLF is separated from the OLV and the OLV is launched. Backup is provided for each type of orbital payload (spacecraft, tanker, and S-IIB stage) so that if unrepairable failure occurs in earth orbit, its spare can be brought up immediately.

3.0 STUDY APPROACH

The basic purpose of the OLF study was to provide reasonable estimates of the design, development, testing, and operating requirements for an orbiting facility that provided the needed support in the orbital launch of a manned interplanetary vehicle.

3.1 Objectives. - Main objectives prescribed for the OLF study were:

1) Conceptually design, with sufficient design details to provide a good basis for cost data, an initial OLF for supporting manned planetary and/or lunar ferry missions;

2) Determine the operational activities that dictate gravitational design criteria and postulate whether a zero-gravity or artificial-gravity type OLF is required;

3) Identify the supporting research and technology problems associated with the development of the initial OLF and prescribe R&D tasks required to solve these problems;

4) Develop a design evolution for the OLF from early ORLs through possible facility concepts for advanced mission support;

5) Establish ORL experiments necessary in the development of the OLF;

6) Determine feasibility and design effects of conducting scientific research and experiments aboard the OLF.

3.2 Study Plan. - The prime effort of the OLF study was the conceptual design of the facility itself. This was necessary to provide the base for the other study evaluations. To accomplish the conceptual design, the numerous supporting studies required included operational analyses, parametric configuration investigations, on-board systems studies, and OLF development and evolution studies. Other special studies were performed to fulfill additional program objectives.

Figure 3.2-1 summarizes the OLF study plan. The parametric conceptual-design studies used basic functional requirements--established by preliminary OLF operational analyses, and other studies including (AOLO and SCALE)--to establish a typical design to meet those requirements. The design was then varied to suit changing parameters of crew size, types of on-board power, artificial gravity provisions, hangar volume, and on-board propellant-storage provisions for the orbital-launch-mission vehicle. Operational studies were planned to investigate the OLF operational requirements within the orbital launch operations, to establish basic functional requirements for on-board systems, and to determine the actual service, maintenance, and repair requirements. Additional operational studies were made to determine the crew requirements for assembly, operating, servicing, and maintaining and repairing the OLF, to establish the initial and resupply needs of spares and expendables and to establish an acceptable logistics program to provide for routine resupply and crew rotation. The OLF on-board

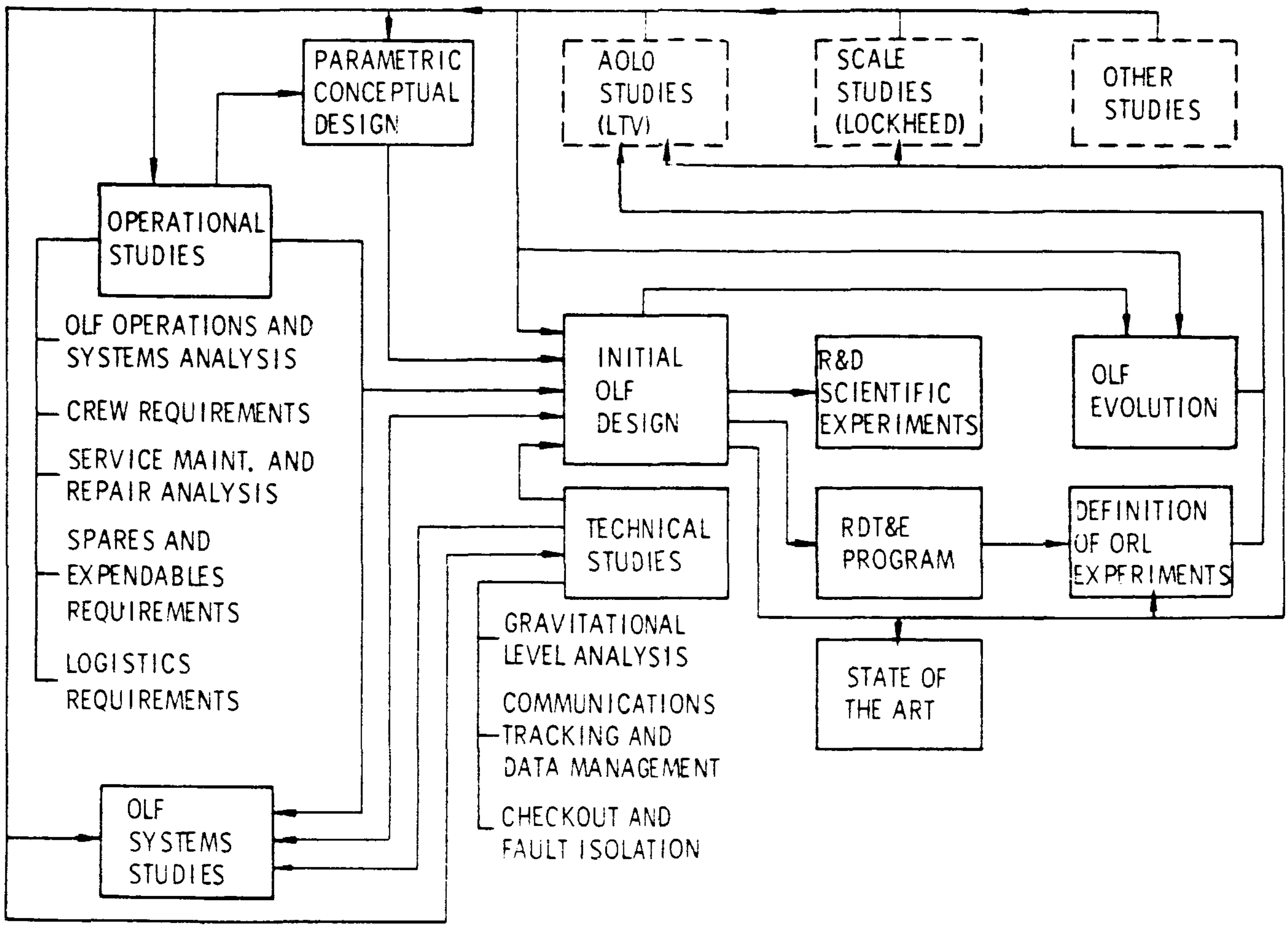


Figure 3.2-1

systems studies were planned to utilize data and functional requirements generated in the operational studies, technical studies, and other space station investigations to provide a full complement of on-board systems that would fulfill the functional needs of the facility and would be within the projected state-of-the-art of the postulated time period. The results of the operational studies, OLF on-board systems studies, parametric conceptual design studies, and technical studies would then be integrated into the initial OLF design. In this interative process, the facility's design would be influenced by, and in turn would influence, the results of these other supporting studies. Once the initial OLF design was established the study plan called for investigation of possible OLF evolution to a facility capable of supporting advanced missions that allowed: (1) establishment of a research, development, testing and engineering (RDT&E) plan; (2) review of the capabilities of the initial OLF in regards to supporting other orbital research, development, and scientific activities on board the OLF during periods between orbital launch operations; and (3) definition of orbital research experiments that may be necessary for the development of the OLF.

The study plan was organized to facilitate the necessary exchange of data between the associated contractors of the OLO studies. Figure 3.2-2 summarizes

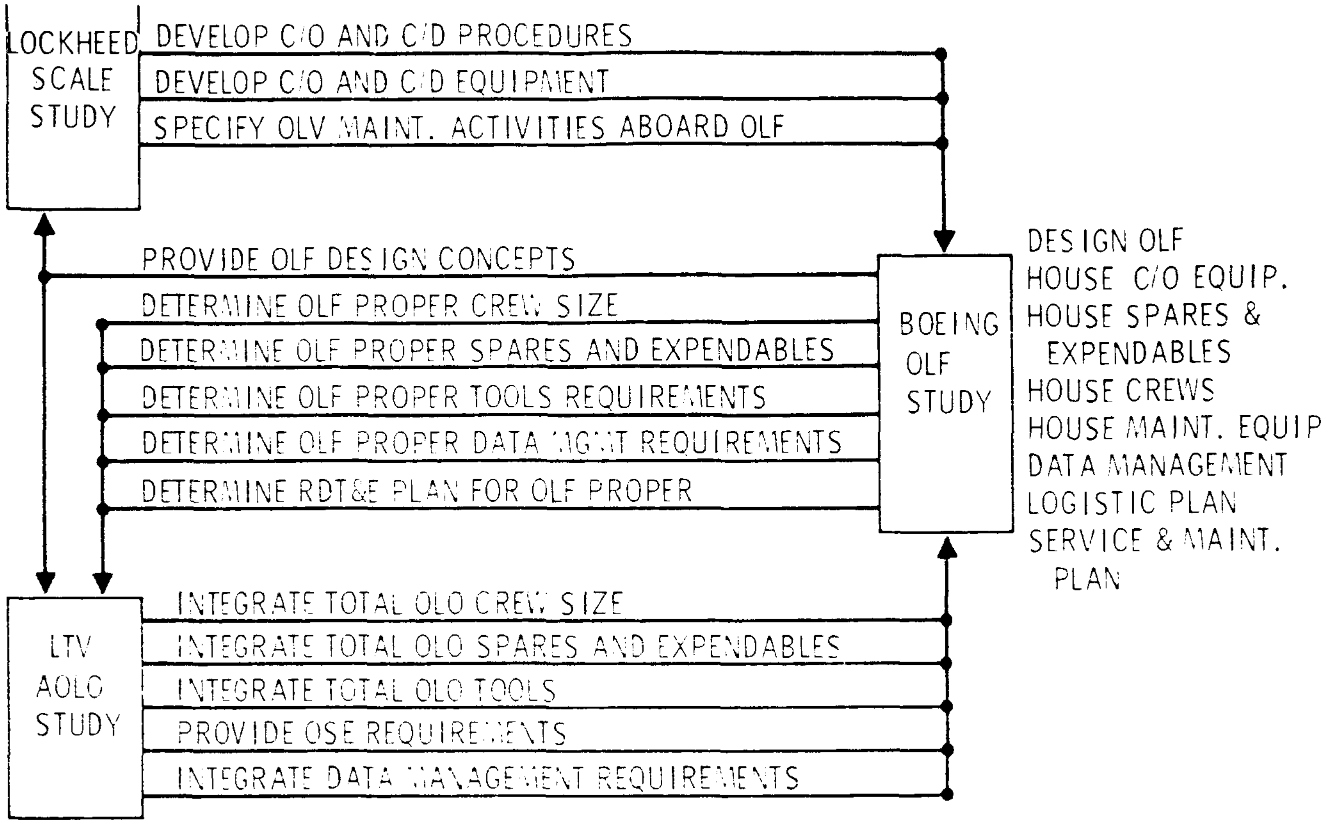


Figure 3.2-2

the anticipated interchange of data, specifically affecting the OLF study, that would occur during the course of the study.

For reporting purposes the results of the OLF study were organized under the headings of Operational Studies, Design Integration, Special Studies, and OLF Development Program; they are previewed in that order through the remainder of this document. The brief reviews of each of these study areas are numbered with the same numbers of corresponding sections in the detailed technical report of Volumes IIA and IIB for easy cross reference.

4.0 OPERATIONAL STUDIES

Operational studies included analyses of OLF operations, service, maintenance and repair, crew requirements, spares and expendables, and logistics. Inasmuch as this was primarily a conceptual design study, these operational studies were carried only to the point at which the design requirements were established or the operational feasibility of unfeasibility of a particular design concept was apparent.

4.1 Operations. - Operations involving the OLF can be divided into four phases: (1) prelaunch; (2) Earth launch, orbital assembly, and checkout; (3) orbital launch operations, per se; and (4) scientific and R&D operations. Analyses of these phases and their implications upon the design of a facility for supporting an orbital launch operation indicated that prime considerations of this study should be directed at the second and third phases listed above. Because this study was one of three--each studying a related part of the total orbital launch operations--it was directed to confine its analyses of the orbital launch operations phase to the routine operations of the OLF proper. Analysis of the actual launch operations including orbital launch vehicle rendezvous, docking, assembly, checkout, and launch, was directed to be left to the other study contractors.

4.1.1 OLF-Earth Launch, Orbital Assembly and Checkout. - The baseline OLF concept, evolving from the variety of concepts considered in the parametric design studies, attempted to make maximum use of planned hardware. The OLF, whose design utilizes planned hardware concepts as building blocks, is launched by a single Saturn V launch vehicle. The initial OLF design evolved through detail design iteration studies of this baseline concept. The operational sequence of the launch and erection of the initial OLF and the major events are shown in Figure 4.1-1.

Analyses from an operational standpoint were made by using event-logic networks for defining and sequencing the events, function and task analyses for defining the tasks, and crew skills requirements and time-line analyses for crew scheduling and time phasing the operations.

It was found that the initial OLF concept needed only about 106 manhours of work in the particular skills, summarized in Figure 4.1-2.

Of the 106 manhours, approximately 11.4 manhours of extravehicular time is required, and about 14.0 manhours of shirtsleeve/oxygen mask time (in a 3.5 psi environment within the facility) is required. Crew scheduling of a basic five-man crew resulted in a total time between OLF launch and the time that it is ready for orbital launch operations of about 55 hours. This assumed a nominal mission in which 4 hours is allowed for minor maintenance and repair, but no major malfunction is encountered. Considering Earth launch facilities constraints on the overall orbital-launch operations, a reasonable margin of time for OLF checkout and deployment, and an allowance for backup OLF launch in case of abort, the latest date and the OLF should be launched is at T minus 152 days from the actual OLV orbital launch.

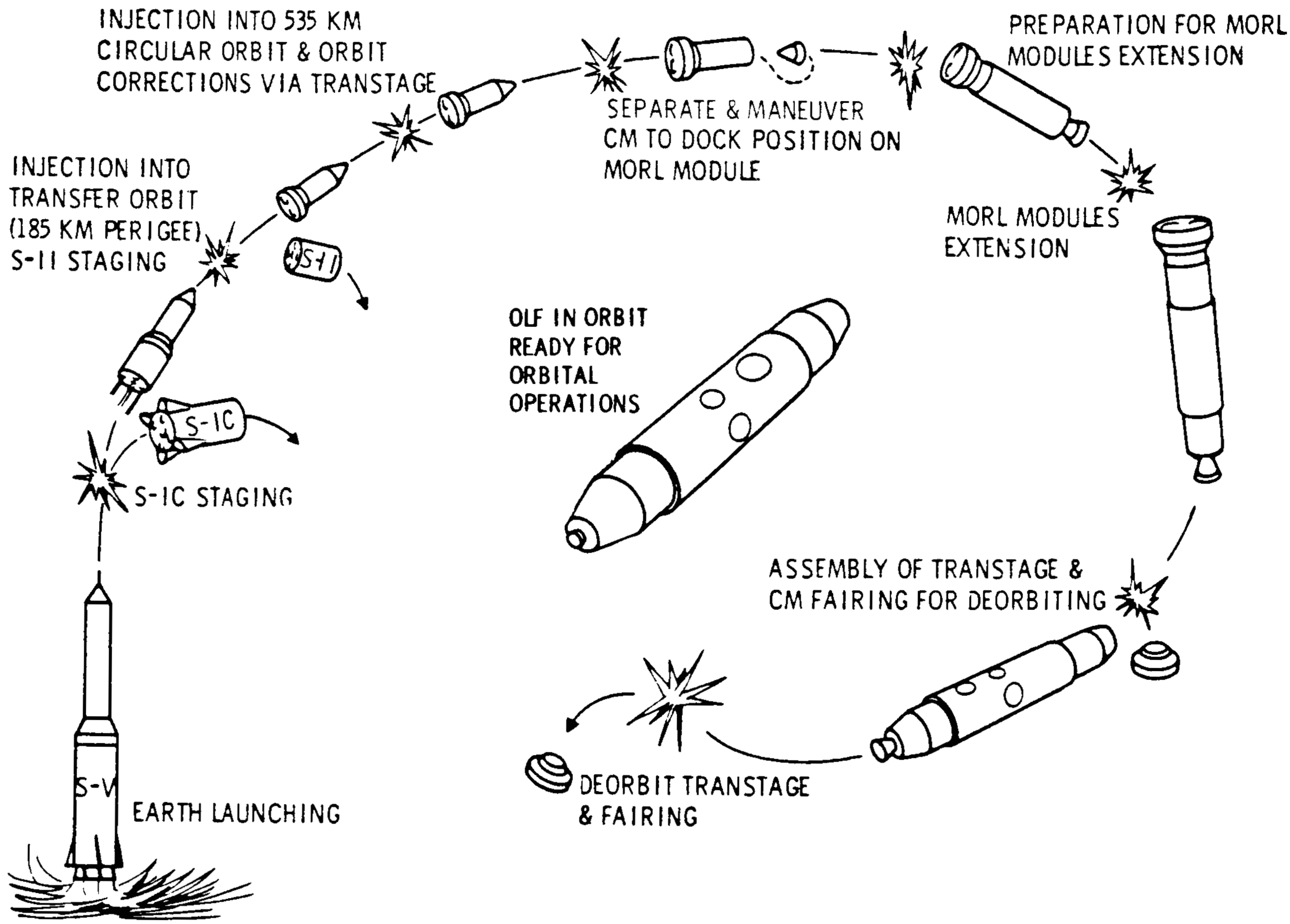


Figure 4.1-1

4.1.2 Orbital Launch Operations--OLF Routine Operations. - The routine operations of the OLF can be divided primarily into station operations, maintenance operations, and personnel operations. Station operations include systems monitoring; navigation, attitude correction, and orbital maneuvers; logistics operations at the OLF; station housekeeping; and operation of the station for artificial gravity. Although scheduled and unscheduled maintenance are not discussed here because they are analyzed separately and discussed in Section 4.2, maintenance times were included in the total work analysis and crew utilization studies herein. Through function and task analyses and time-line analyses of the OLF routine activities, it was found that approximately 24 manhours of daily work, 15.5 manhours of weekly work, 6 manhours of monthly work, and 19 manhours of work every 90 days is required in station operations. Personnel operations includes crew condition assessment, crew training and emergency drills, personal care, relaxation and conditioning, nutrition, and sleep. The total time requirements for these operations are obviously dependent upon the number of crew members. For this study the individual time allocations for each of these activities were: (1) crew condition assessment -- 1.5 hours/man/week; (2) crew training and emergency drills -- 4 hours/man/week; (3) personal care -- 1.5 hours/man/day; (4) relaxation and conditioning -- 2 hours/man/day; (5) nutrition --

FIGURE 4.1-2 OLF LAUNCH ORBITAL ASSEMBLY & CHECKOUT WORK AND SKILL REQUIREMENTS SUMMARY

Skill	Manhours
Flight Command Operations	12.6
Console Operations and Checkout	*20.2
Environmental Control System	14.2
Mechanical	19.5
Structural	15.8
Electronic/Electrical	8.5
General	14.9
Total	105.7 man/hrs

* These times include the active console work required by a particular task, but not routine console standby.

2.5 hours/man/day; and (6) sleep -- 8 hours/man/day. The average daily time required for personnel operations was approximately 14.8 hours/man.

Results of an analysis of the routine operational crew time requirements, including maintenance requirements from Section 4.2, for one year for varying crew sizes, are shown in Figure 4.1-3. Crew requirements, based on this analysis are discussed in Section 4.3.

4.2 Maintenance Plan. - The OLF will be the center of orbital service, maintenance, and repair activity for a permanent-facility mode of orbital-launch operation. As such it must provide for these activities for all of the associated orbital equipment, including the checkout and launch equipment, rescue and logistics spacecraft, the OLV, tankers and other orbital support equipment, as well as for the OLF itself. This study first investigated the service, maintenance and repair operations of the OLF proper; then, using inputs from other associated orbital launch operation studies, integrated the requirements of all the orbiting systems into the facility's design.

The OLF proper service, maintenance and repair study was based upon the following philosophy and guidelines:

1) The OLF design should minimize extravehicular activity, provide for ease in system service, maintenance, and repair with a minimum use of tools, make

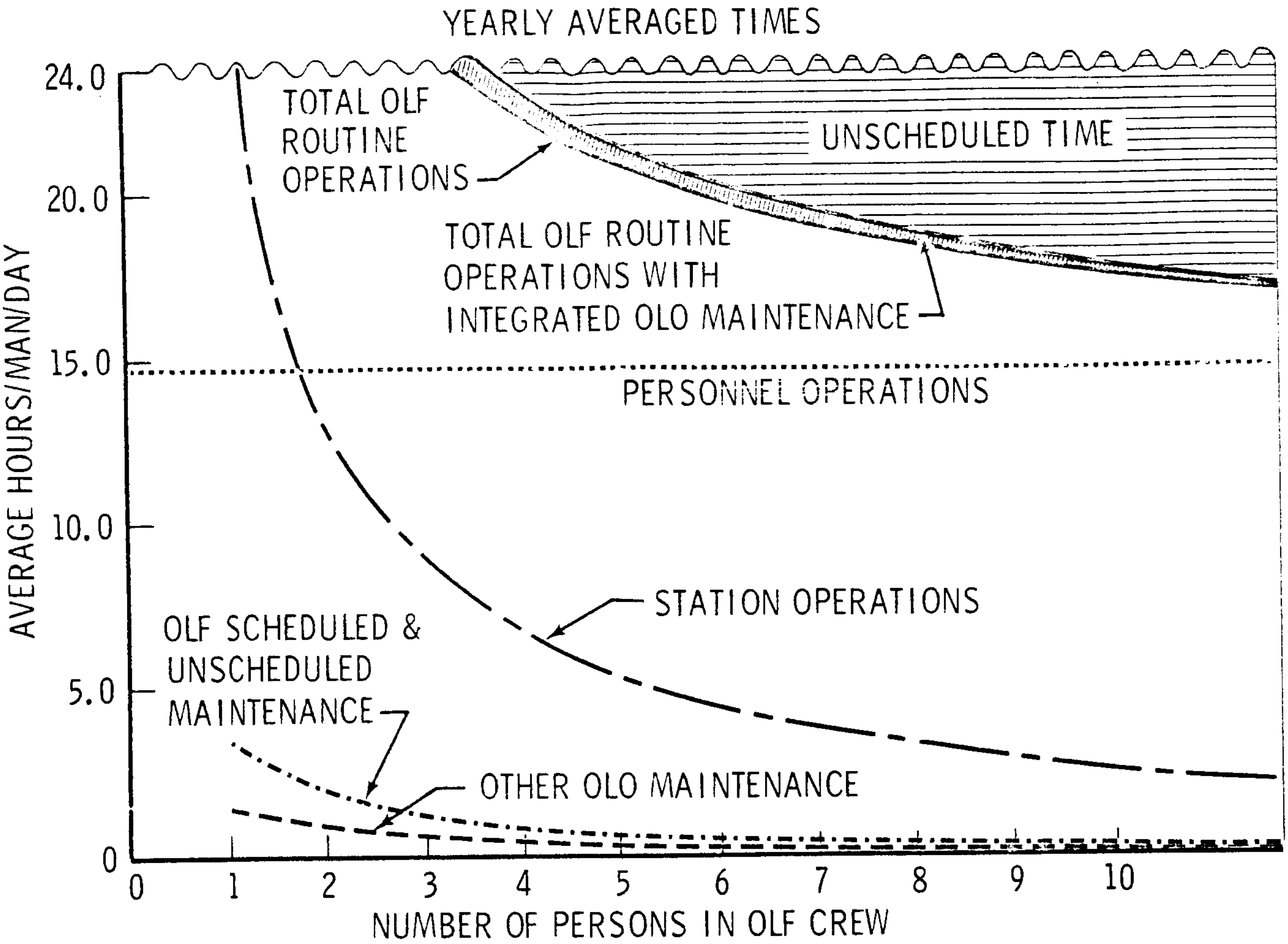


Figure 4.1-3

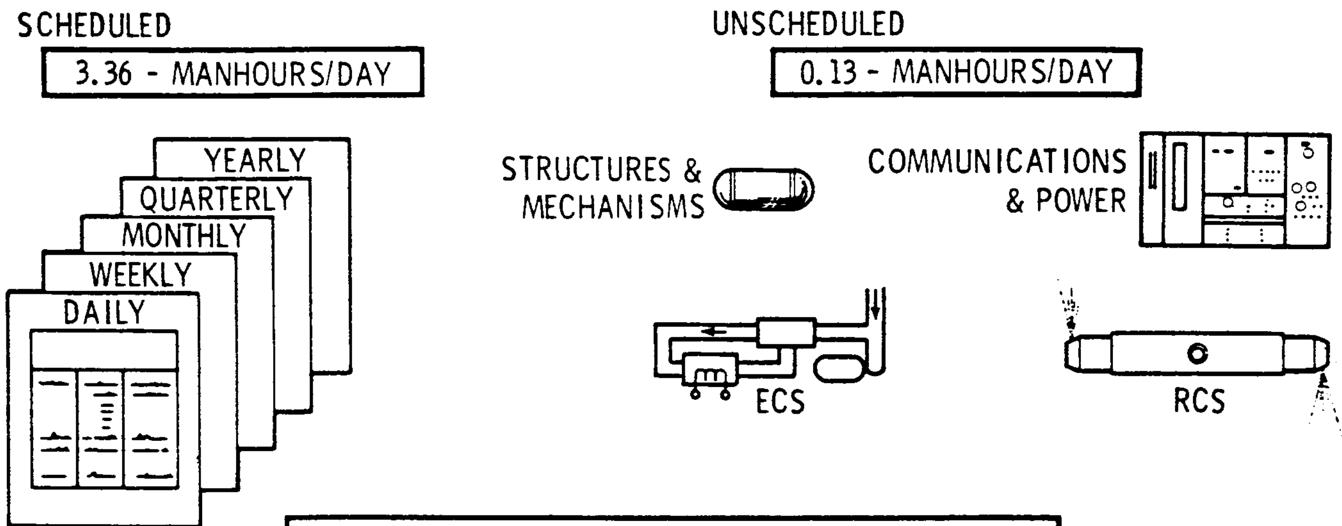
optimum use of spares, and provide shop area for minor repairs.

2) Full use of man should be made in maintenance functions, and each crewman should be fully qualified in at least one secondary skill.

3) Extravehicular activity increases work expenditure 35% over that required in a normal shirtsleeve environment and spacesuit operations are limited to 4 hours of useful work per man-shift.

4) The probability of spare availability is assumed to be .99 for 90 days, with the initial supply of spares sufficient for 45 days beyond the regular resupply period.

For each OLF subsystem an analysis was made of major assemblies and elements, their operating times, failure rates, maintenance functions, spares requirements, repair time, skills, and tool requirements. This analysis provided the basis for the summary of maintenance requirements of the OLF proper, shown in Figure 4.2-1, which shows scheduled and unscheduled maintenance, averaging the totals for daily, weekly, monthly, quarterly, and yearly tasks to give an average daily

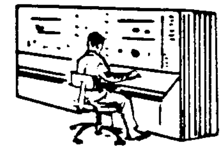


TOTAL OLF MAINT. — 3.49 MANHOURS/DAY			
AVERAGE MANHOURS PER DAY			
FUNCTION	ELEC/ELEC	LS/ECS	STRUCT/MECH
SCHEDULED	0.44	2.39	0.53
UNSCHEDULED	0.06	0.02	0.05
TOTAL	0.50	2.41	0.58

Figure 4.2-1

figure. Maintenance requirements are accumulated by skill and totaled. Figure 4.2-2 shows accumulated averages of daily, weekly, monthly, 90-day, and yearly requirements carried into the integration of all maintenance required by the OLF proper, checkout equipment, the logistics spacecraft, and OSE. The total average maintenance workload for the OLF is 5.02 manhours/day, of which 4.66 manhours/day are scheduled maintenance and 0.36 manhours/day are predicted unscheduled maintenance.

4.3 Crew Requirement. - The objective of this portion of the study was to determine just how many people with which skills are required to assemble and ready the OLF for orbital launch operations and sustain it during those other possible orbital operations. It should be emphasized that this exercise did not include the establishment of checkout crews to prepare, checkout, and launch the OLV although the OLF design requirements were of course, based upon the total integrated crew requirements. The data required for this analysis were accumulated from the operations and service, maintenance, and repair analyses in the form of manhours for each of the various skills required.



AVERAGE MANHOURS PER DAY			
FUNCTION	ELECT/ELEC	LS/ECS	STRUCT/MECH
SCHEDULED			
OLF PROPER	0.44	2.39	0.53
C/O EQUIP	0.50	—	—
LOGISTIC SC	0.20	0.20	0.10
OSE	0.10	0.10	0.10
UNSCHEDULED			
OLF PROPER	0.06	0.02	0.05
C/O EQUIP	0.05	—	—
LOGISTIC SC	0.03	0.03	0.03
OSE	0.03	0.03	0.03
TOTAL MANHRS/DAY	1.41	2.77	0.84

TOTALS		
SCHEDULED	4.66	MANHRS/DAY
UNSCHEDULED	0.36	MANHRS/DAY

Figure 4.2-2

In analyzing the routine operations and service, maintenance, and repair operations, it was assumed that normal personnel operations, as listed in Figure 4.3-1, would suffice. However in the OLF launch, assembly, and checkout operations, it was felt that over the short period involved in these operations, a higher activity schedule could be used. This increased the work time to 11.5 hours/man/24-hour period, reduced the sleep time to two 3.5-hour sleeping periods/24-hour period, and reduced the relaxation (exercise and leisure) time 0.5 hours/24-hour period. This high activity schedule is also shown in Figure 4.3-1. Referring to Figure 4.1-3, it is evident that the three-man crew would not be capable of performing the routine operations of the OLF without reducing their personnel operations time. A four-man crew is utilized on the average about 95% of the available time. Personnel operations occupy 62% of each man's time, 27% is used in station operations and about 6% in maintenance activities. In time-line analyses performed for these studies, it was found that at least 3- to 5% of the total time inherently became slack time because of the scheduling problems. Because the times indicated by the curves of Figure 4.1-3, are averaged times, it can be expected that some days may be of higher activity. In this case the unscheduled time must be utilized and, perhaps, even some adjustment of

FIGURE 4.3-1 OLF CREW TIME DISTRIBUTION ASSUMPTIONS

	Normal Schedule	High Activity Schedule
Sleep	8.0	7.0 (2 x 3.5)
Personal Care	1.5	1.5
Nutrition	2.5	2.5
Relaxation - Exercise	1.0	1.5
- Leisure	1.0	
Work	10.0	11.5
	24.0 hrs.	24.0 hrs.

personnel operations time may be necessary. Nevertheless, it was evident that a four-man crew would be the smallest crew that could reasonably perform the routine operations of the OLF.

In the OLF launch, orbital assembly, and checkout phase, there were operations, particularly checkout operations, much more effectively accomplished by a five-man crew than a four-man crew. Inasmuch as checkout people were required in orbit as soon as the OLV is launched from Earth and docked to the OLF, the most effective number of personnel to accomplish the launch, assembly, and checkout phase was considered to be five. A time-line analysis of this high-activity phase of the operation showed that 39% of the total crew time was used in active work; 10% on standby (console monitoring); 3% in unscheduled time; and the remaining 48% in sleep, nutrition, personal care, and relaxation. The most pronounced skill requirements are dictated by the maintenance and repair operations, whereas the skills required in the assembly and checkout phase are generally at a "checkout" level, which might be slightly lower than that of a repair specialist. The crew requirements of the OLF proper are summarized in Figure 4.3-2.

4.4 Spares and Expendables. - The quantity of spares to be carried on board the OLF is a function of their reliability, weight, and volume and the total reliability required of the orbiting systems. In this study's analysis, the basic assembly listings, operating times, and failure-rate information provided by the maintenance analysis, and similar data on orbital support equipment and checkout equipment provided by associated studies, were fed into a computerized Boeing spares model and the spares costs (in volume and weight) versus the probability that the proper spare would be available was calculated. Data from those calculations are presented in Figure 4.4-1. For a 0.99 probability of having the correct spare, the initial spares weight requirement is 3517 kg (7754 lbs.) total. The spares resupply requirements were calculated by the same computer program for

FIGURE 4.3-2 CREW REQUIREMENTS -- OLF PROPER

CODE	PRIMARY SKILL	SECONDARY SKILL	NUMBER
FCO	Flight Commander	Struct/Mech.	1
E/E	Electrical/Electronics	Life Supp/ECS & Asst. FCO	1
LS/ECS	Life Support/ECS	Electrical/ Electronics	1
S/M	Structures/Mechanisms	Life Supp/ECS	1
* C/O	Checkout	Struct/Mech.	1

* This man is required during assembly and checkout of the OLF and during OLO as part of the SCALE crew, but is not then required as part of the OLF crew in routine operations.

FIGURE 4.4-1 INTEGRATED OLF INITIAL SPARES WEIGHT

Integrated System	Probability of Correct Spare	Mass kg	(lbs.)
OLF	0.99710	1155	(2546)
Checkout Equipment	0.99930	68	(150)
Logistics Spacecraft	0.99913	247	(545)
Orbital Support Equipment	0.99990	199	(438)
Orbital Launch Vehicle	0.99450	1433	(3160)
Orbital Tankers	0.99949	415	(915)
Total	0.99005	3517 kg	(7754 lbs.)

one hundred 90-day cycles. The maximum, minimum, and average spares resupply requirements were found to be 403 kg (889 lbs.), 40 kg (89 lbs.), and 140 kg (309 lbs.) respectively.

Two of the primary expendables aboard the OLF, which could significantly affect the facility's design, are the life-support supplies and propellants. Unlike the spares, the quantities of life-support supplies and propellants are not directly dependent upon the desired systems reliability, but have mandatory resupply requirements for crew survival and systems functioning. Life support consumption (or resupply) is presented in Figure 4.4-2 as a function of crew size. Figure 4.4-3 presents OLF propellant usage curves used in the investigation of a spinning (for artificial gravity) and non-spinning OLF. In a non-spinning condition, which is recommended for the orbital launch operations, the propellant consumption during the 170-day OLO shown is approximately half that of the spinning mode of operation.

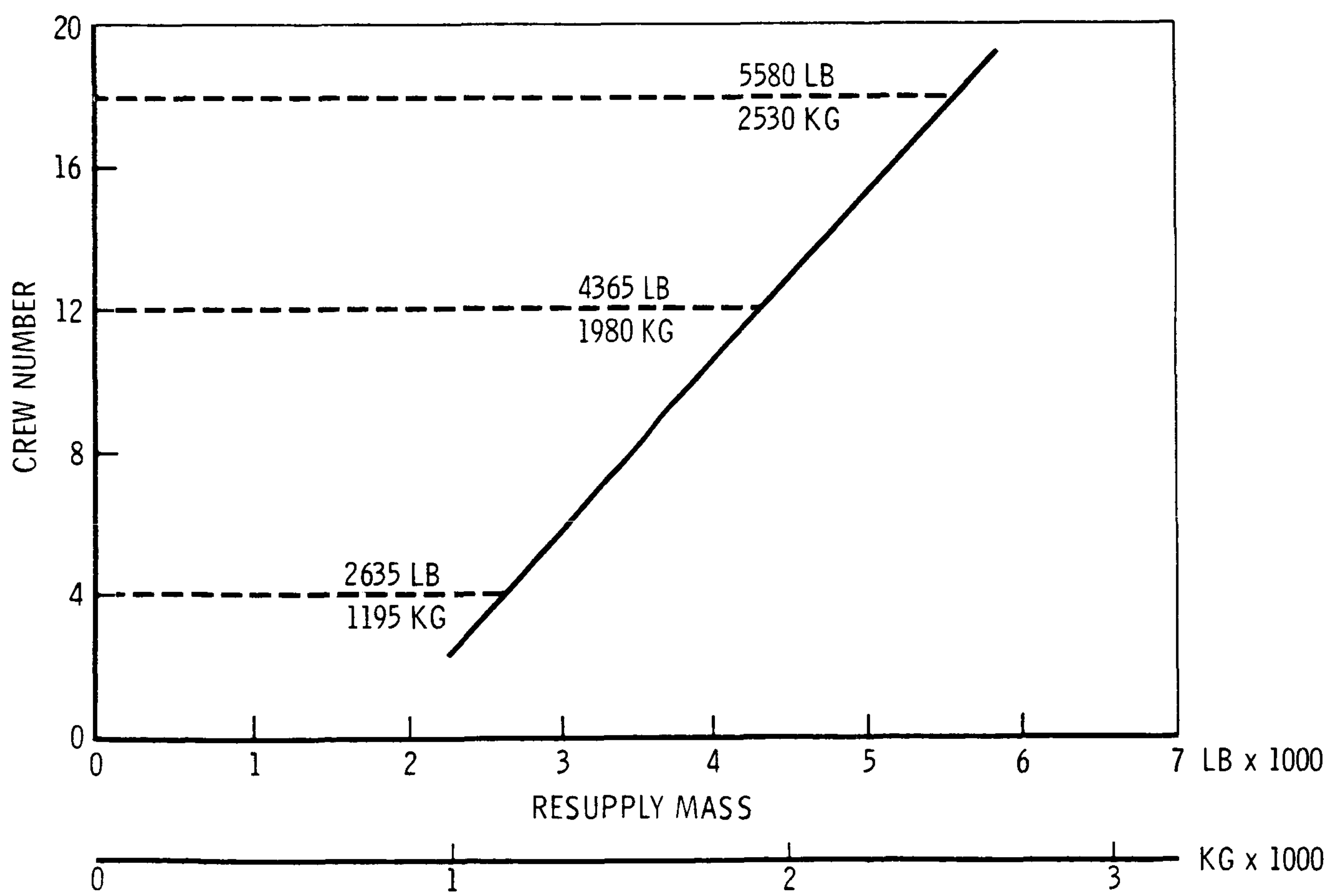


Figure 4.4-2

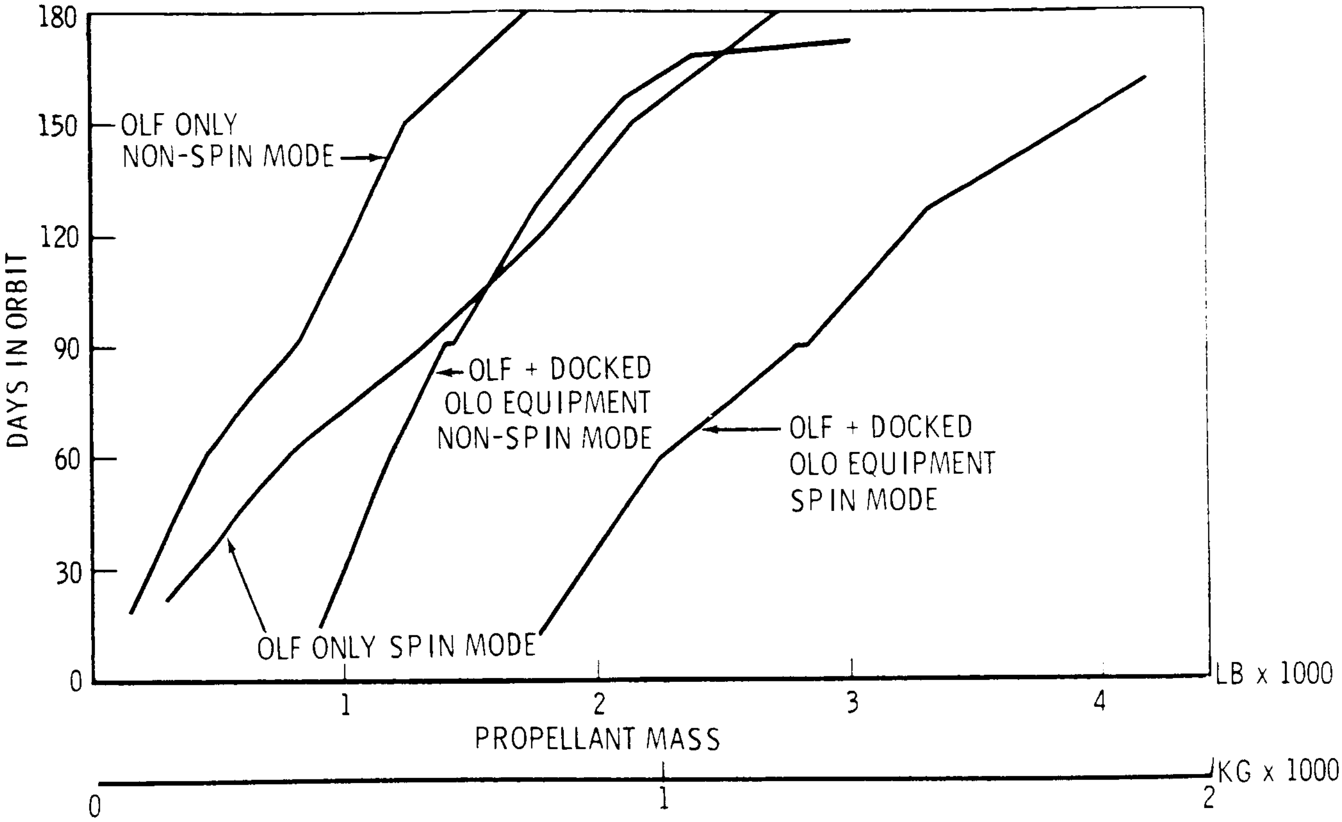


Figure 4.4-3 : PROPELLANT USAGE COMPARISON

4.5 Logistics. - The analysis of the logistics operations was based on the following guidelines and assumptions.

1) The initial OLF launch will be via Saturn V; the high payload capability alleviates some of the burden on subsequent logistics launches;

2) Six-man Apollos having service module sections with 12,000 lb. payload capability, plus crew, will be used as logistics spacecraft;

3) Crew rotation will be every 180 days, with logistics spacecraft being launched every 90 days.

Logistics requirements were determined for three possible conditions of OLF operation: (1) the first OLF put into orbit was considered operational and is ready for orbital launch operations imediately following assembly and checkout; (2) the first OLF put into orbit requires 60 days of orbital testing, then is used for 330 days in OLO operations rehersal, and is finally used for the actual orbital launch operations that commences 390 days after the Earth launch of the OLF; and (3) post-OLO operations.

For the first condition the supplies and expendables intended for accompanying the OLF on the initial launch are summarized in Figure 4.5-1. The entire quantity of propellant required for supporting the OLF and associated equipment until after the orbital launch is supplied in this initial launch of the OLF. The logistics support profile for the initial OLF is shown in Figure 4.5-2. As the figure shows, the initial launch of the OLF carries 14,051 kg (30,978 lbs.) of spares and expendables and five crewmen. Ninety days later a logistics spacecraft is launched, carrying a crew of three and 1548 kg (3416 lbs.) of replacement supplies. This crew supplements the initial crew, giving a total of 8 men in the OLF. The next logistics launch carries 2387 kg (5266 lbs.) of supplies, two OLF crewmen, and the three OLV crewmen. At this time there are 13 men aboard the OLF. This launch occurs just 11 days prior to the OLV orbital launch. Following the orbital launch, the original five crewmen and one crewman from the second group will return to Earth. This leaves a crew of four manning the OLF, half of which will be rotated each subsequent 90-day period.

FIGURE 4.5-1 SUPPLIES AND EXPENDABLES

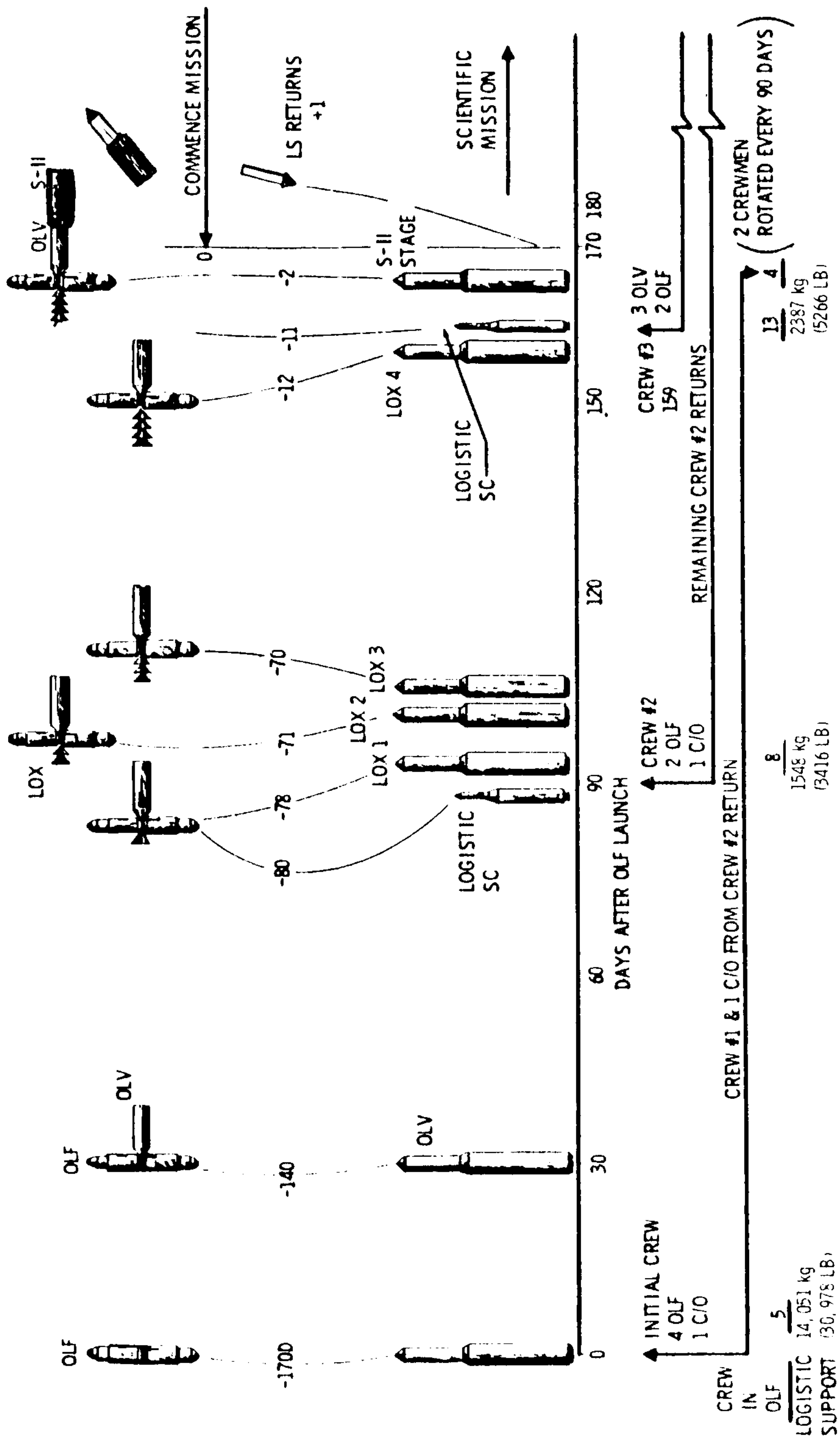
INITIAL LAUNCH:

- LIFE SUPPORT FOR 135 DAYS FOR 12 MEN
- PROPELLANTS FOR 170 DAYS
- SPARES FOR 135 DAYS

WEIGHT SUMMARY:

. LIFE & CREW SUPPORT Food-O_2N_2- Pers. Equip-ECS Expendables	5,579 kg (12,299 lbs.)
. PROPELLANTS OSE-Orbit Keeping - Attitude Control	1,838 kg (4,052 lbs.)
. SPARES OLF - C/O Equip. - OSE - LS/C	3,517 kg (7,754 lbs.)
. MAINTENANCE TOOLS & EQUIP.	118 kg (261 lbs.)
. OLV SUPPLIES	2,999 kg (6,612 lbs.)
TOTAL	14,051 kg (30,978 lbs.)

This first condition spans a period of 170 days between the Earth launch of the OLV and the orbital launch of the mission spacecraft. During this period two logistics spacecraft will be launched from Earth in addition to four



COMMENCE MISSION
LS RETURNS +1
SCIENTIFIC MISSION
OLV
S-II
S-II STAGE
LOX 4
LOGISTIC SC
LOX
LOX 1
LOX 2
LOX 3
OLF
OLV
-1700
-140
-80
-78
-71
-70
-12
-11
-2
0
0
30
60
90
120
150
170
180
DAYS AFTER OLF LAUNCH
CREW IN OLF
INITIAL CREW 4 OLF 1 C/O
CREW #1 & 1 C/O FROM CREW #2 RETURN
CREW #2 2 OLF 1 C/O
REMAINING CREW #2 RETURNS
CREW #3 159
3 OLV 2 OLF
2 CREWMEN ROTATED EVERY 90 DAYS
LOGISTIC SUPPORT
5
14,051 kg (30,975 LB)
8
1548 kg (3416 LB)
13
2387 kg (5266 LB)
4

Figure 4.5-2

LOX tankers, one S-II stage containing H_2 propellant, and one OLV spacecraft. The total logistics mass delivered in this condition--including OLV propellants, OLV spacecraft mass, and OLF and OLV supplies and expendables--is 551,595 kg (1,216,065 lbs.).

The second operational condition or alternate plan including orbital testing spans a period of 530 days between the Earth launch of the OLF and the orbital launch of the mission spacecraft. Figure 4.5-3 summarizes the logistics plan for this condition, beginning with an initial supplies and expendables requirement of 14,171 kg (31,239 lbs.). The quantities of additional supplies and expendables delivered on each subsequent logistics launch are shown along the lower part of the figure. During this 530-day period, six logistics spacecraft will be launched, five LOX tankers, two S-IIB stages containing H_2 propellant, and two OLV spacecraft. The total logistics mass delivered in this condition--including OLV propellants, OLV spacecraft mass and OLF and OLV supplies and expendables--is 782,300 kg (1,724,685 lbs.).

The third condition, logistics requirements, requires routine 90-day resupply for post-OLO activities, and is dependent upon the total number of personnel on board the OLF and the type of activity which it is engaged in. For an assumed crew of twelve on board the OLF, the logistics resupply every 90 days would be 2,830 kg (6,265 lbs.).

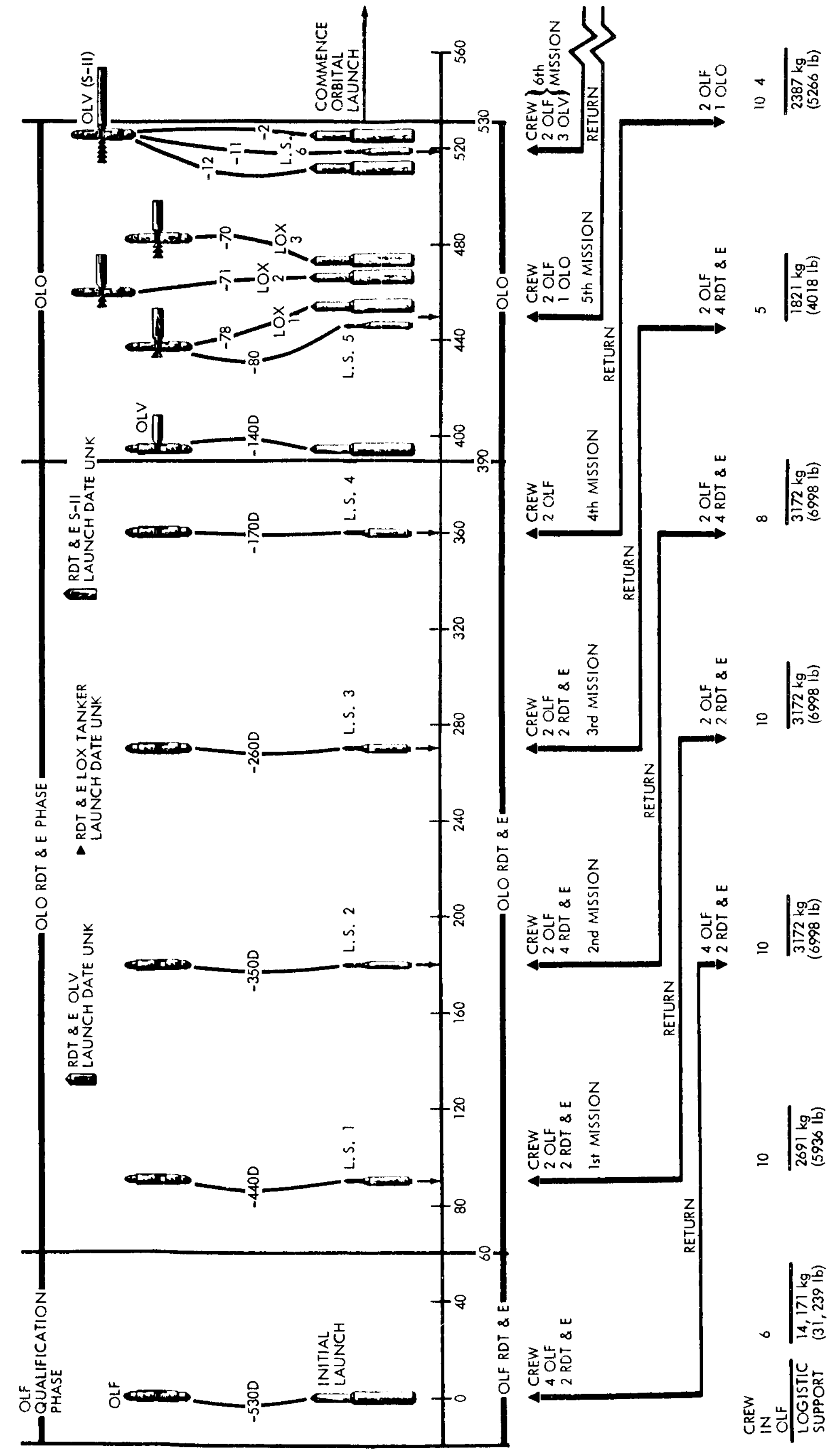

OLF QUALIFICATION PHASE
OLO RDT & E PHASE
OLO
OLF
-530D
INITIAL LAUNCH
RDT & E OLV LAUNCH DATE UNK
RDT & E LOX TANKER LAUNCH DATE UNK
RDT & E S-II LAUNCH DATE UNK
-440D
-350D
-260D
-170D
-140D
L. S. 1
L. S. 2
L. S. 3
L. S. 4
L. S. 5
L. S. 6
OLV
-80
-78
-71
-70
-12
-11
-2
LOX 1
LOX 2
LOX 3
OLV (S-II)
COMMENCE ORBITAL LAUNCH
0
40
60
80
120
160
200
240
280
320
360
390
400
440
480
520
530
560
OLF RDT & E
OLO RDT & E
OLO
CREW 4 OLF 2 RDT & E
CREW 2 OLF 2 RDT & E
1st MISSION
CREW 2 OLF 4 RDT & E
2nd MISSION
CREW 2 OLF 2 RDT & E
3rd MISSION
CREW 2 OLF
4th MISSION
CREW 2 OLF 1 OLO
5th MISSION
CREW 2 OLF 3 OLV 6th MISSION
RETURN
4 OLF 2 RDT & E
2 OLF 4 RDT & E
2 OLF 2 RDT & E
2 OLF 4 RDT & E
2 OLF 4 RDT & E
2 OLF 1 OLO
CREW IN OLF
6
10
10
10
8
5
10 4
LOGISTIC SUPPORT
14,171 kg (31,239 lb)
2691 kg (5936 lb)
3172 kg (6998 lb)
3172 kg (6998 lb)
3172 kg (6998 lb)
1821 kg (4018 lb)
2387 kg (5266 lb)

Figure 4.5-3

5.0 DESIGN INTEGRATION

Concurrently with the start of operational studies, design studies were also initiated. It was necessary that the OLF design effectively meet the orbital-launch operational requirements and the design requirements derived from the operational studies discussed in the previous section.

5.1 Design Approach. - The first step in the development of the design was to establish general design objectives. These were based upon past orbital-launch-operation studies. With these general objectives in mind, a parametric design study was conducted. Configurations were devised and major design parameters that broadly affected the concept, such as vehicle size and type of on-board power, were varied. In addition, the use of existing design concepts, such as the AES and MORL, as building blocks in the design of the OLF was investigated. An evaluation was then made of the various concepts--based upon cost, size, weight, and other parameters--and a concept was selected from which the baseline design was developed and specific design criteria were generated. The baseline design, subjected to design iterations as the various operational, design, and technical studies were accomplished, eventually evolved into the initial OLF.

5.2 Baseline Selection. - Early on the study a list of major design objectives was established for the OLF. These objectives, considered goals rather than specific design criteria, were selected in large part through an examination of earlier studies on orbital launch operations that had been conducted by Ling-Temco-Vought. Specific design objectives were:

(1) Provide a hangar for the orbital support equipment;

(2) Make optimum use of existing concepts as building blocks in the OLF design (i.e., MORL, AES);

(3) Provide a centrifuge for personnel gravitational conditioning with artificial "g" as an alternate mode;

(4) Provide a maximum of shirtsleeve environment for the crew;

(5) Design for ease of maintenance;

(6) Design to minimize extravehicular time;

(7) Consider growth capability for support of advanced missions;

(8) Design to permit orbital operation requirements to be borne by the OLF with a minimum performance penalty to the mission vehicle;

Within these objectives the parametric design study was accomplished by the results, and on the basis of these evaluations establish design criteria for the OLF baseline concept.

5.2.1 Parametric Study. - The representative concept used as a basis for the parametric studies housed a maximum crew of 18; utilized solar panels for on-board power; and provided a fuel depot, artificial gravity and a hangar for orbital support equipment. Figure 5.2-1 diagramatically illustrates the process for this portion of the study. The parameter variations included: crew size aboard the OLF between 9 and 36 full-time crewmen; nuclear-power effects; zero-gravity-operation effects; effects of having no hangar nor of providing any fuel depot. At the same time a building block approach was investigated to incorporate AES or MORL modules in the OLF design. In this approach two methods of developing the configurations were employed. First, unitized designs were developed in which AES or MORL Modules were used as building blocks. Second, OLF concepts. consisting of individually orbiting modules in sufficient numbers and properly equipped to accomplish the orbital support requirements, were investigated.

At the completion of the parametric configuration study, the various designs were evaluated on the basis of cost, size, weight, complexity, reliability, serviceability, and state-of-the-art and, in consultation with the other associated contractors and NASA, a more specific set of OLF design criteria was established. The primary points of that criteria are listed below:

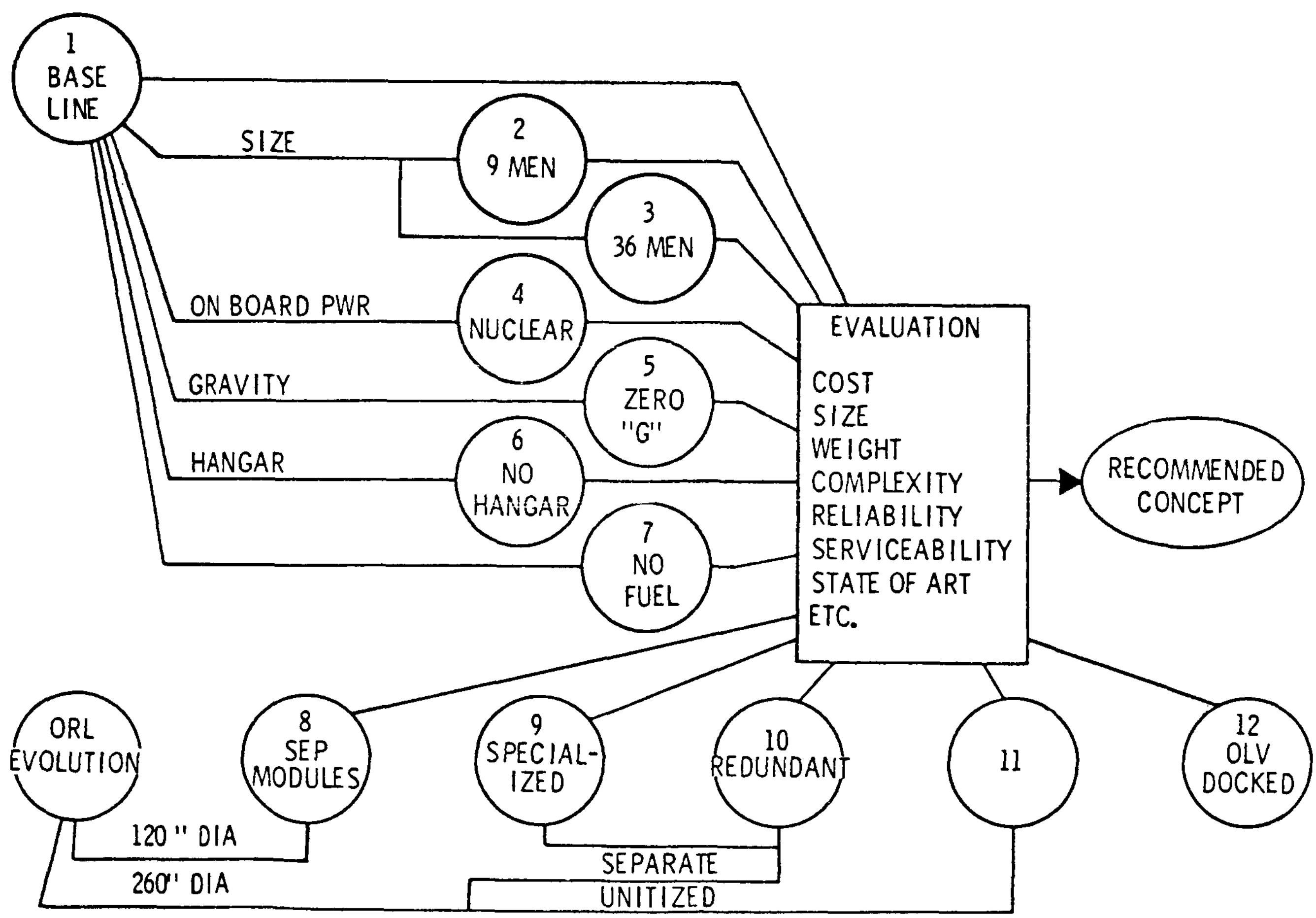


Figure 5.2-1

(1) Five year operational lifetime;

(2) 0.99 probability of no meteoroid penetration for five years;

(3) No major on-board propellant storage, but the orbital tankers and OLV would hard-dock to the OLF during checkout and propellant transfer.

(4) Accommodate at least 12 men, full time, with an overload capacity of 50% for at least 15 days.

(5) Hangar provisions for OSE storage, servicing, and repair;

(6) Use of MORL modules in OLF design;

(7) OLF orbital maneuvering capability;

(8) Spin capability for artificial gravity.

5.2.2 Concept Selection. -Three concepts evolved from these studies and are shown in Figure 5.2-2. The selected baseline OLF concept is shown in the lower right of the figure. It should be noted that during the design-iteration studies following the baseline concept selection the solar panels were replaced in favor of an isotope nuclear system. The baseline utilizes two MORL modules joined by two cylindrical hangar or general service areas and a central hub section. The configuration is designed in such a way that the MORL modules may be retracted into the central cylindrical areas for launch and the entire facility is launched with one Saturn V launch vehicle. No orbital rendezvous is required in the orbital assembly and checkout of this OLF concept.

The middle configuration, labeled Alternate #1, is nearly identical to the baseline except that it does not use the retractable-MORL modules concept, but is divided into several sections that are boosted separately into orbit and must subsequently be rendezvoused and assembled in orbit. Although the assembly operations are considerably more complex, this concept uses smaller launch vehicles--three or more Saturn I-B boosters. Functionally, this concept is very similar to the baseline.

Alternate #2 may be launched complete by four Saturn I-B launch vehicles. It also requires orbital rendezvous and assembly in orbit. It makes maximum use of existing design concepts and, from the standpoint of evolution from early ORL hardware, it appears to be an optimum design. Like the other two concepts, it used MORL modules in the extremities of the facility. These are attached to LEM adapter sections, which in turn are attached to Apollo service-module sections. The LEM adapter and Apollo service-module sections, which are practically bare shells of the intended hardware, contain few of the internal systems intended in their present designs. The service module sections are attached to a specially designed central docking hub.

In the actual concept selection, the baseline concept was found to be much less complex in design and assembly, checkout, and operation of the facility, and it offers considerably more growth potential than Alternate #2. Although Alternate #2 appeared optimum in use of existing hardware design concepts, it was found that

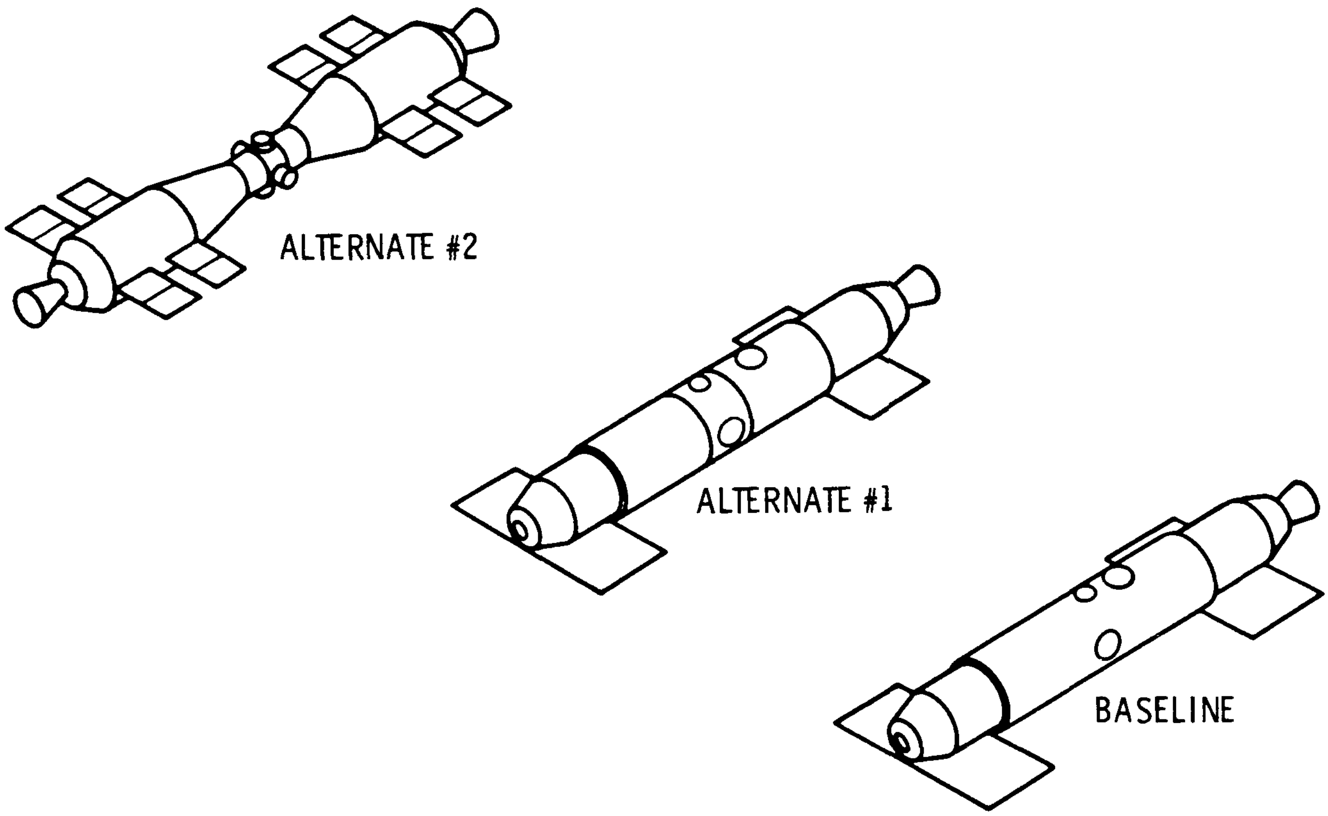


Figure 5.2-2

the modifications required in those designs diminished that advantage considerably. In practically all aspects of launch and assembly comparisons--(probability of successful launch and injection, cost of launching, launch payload utilization, orbital rendezvous and docking, orbital assembly, and launch-imposed design constraints)--the selected baseline concept appeared considerably more favorable.

5.3 Initial OLF Design. - Figure 5.3-1 presents a detailed outline drawing of the initial OLF design as it evolved from the baseline concept. The initial OLF consists of two modified MORL modules connected by a cylindrical section containing a compartmented hub at the center. The upper picture shows the OLF in the launch configuration; the lower one will be deployed in orbit.

The launch configuration has the MORL modules retracted within the cylinder. One end of the cylinder supports a manned Apollo command vehicle and abort tower through a shroud structure. The opposite end attaches to a small injection stage and instrument unit which are mated to the S-II stage of the booster.

After injection into orbit, the MORL modules are extended by gas pressure as they are aligned and restrained by cable mechanisms. The basic structure of the MORL

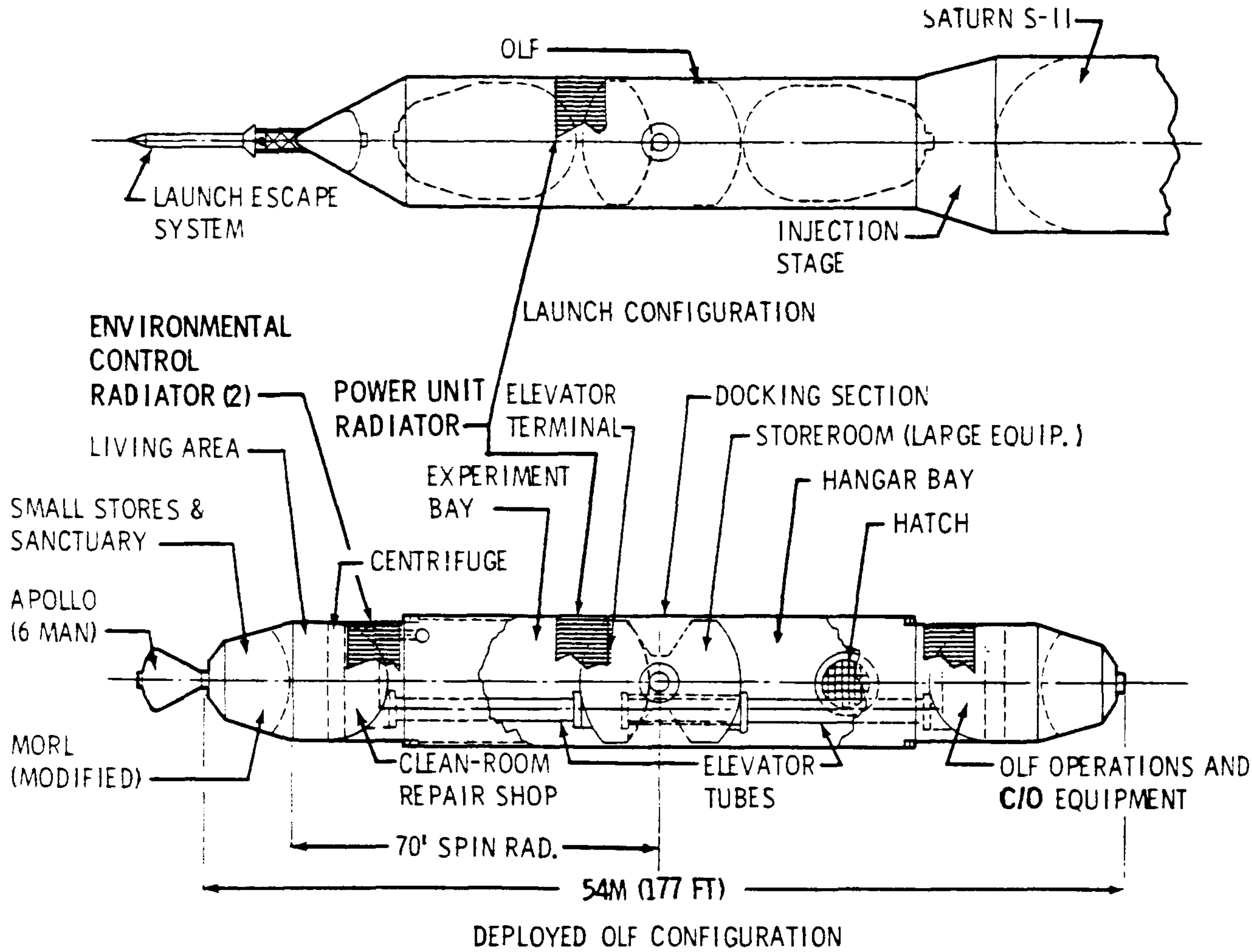


Figure 5.3-1

modules is retained, but compartment usage is somewhat different. The outer compartments are used for storage of supplies such as food, water, oxygen, and small spare parts; they also serve as sanctuaries. The next level toward the hub serves as crew quarters, and the next houses the centrifuge. The inner level on the hub side of the centrifuge of one MORL, the operations area, contains the checkout equipment and OLF controls and displays. The similar level of the other MORL is a shop area for general equipment maintenance and repair.

One large bay between a MORL and the hub is equipped with a 160-inch-diameter hatch and used as a hangar, assembly, and structural repair area. The other such area, having no hatch, is used for storage, exercise, and possibly for space experiments or OLF evolutionary growth. These two large volumes, normally pressurized at 3.5 psia, can be pumped to alternate higher or lower pressure for either hatch opening, or shirtsleeve work.

The hub area has two separate compartments. One of these, called the terminal, is connected by pressurized elevator tubes to both of the MORL modules. The other compartment contains the docking ports as well as storage areas.

5.3.1 Special Features. - Three interesting major design features of the OLF --the central hub section, the elevator system, and the umbilical service unit for the orbital launch vehicle--are described below.

5.3.1.1 Central Hub Configuration. - The OLF hub section (Figure 5.3-2) consists of two major sections. The first, the terminal section, serves as a terminal for the elevator shafts that provide access from the hub to the MORL modules. Three airlocks built into this compartment provide access to the orbital-launch-vehicle spacecraft, the outside of the OLF for extravehicular operations, and the hangar portion of the OLF. A hatch is also provided for access to the other hub section. This section, like the MORL modules and the elevator shafts which physically connect the MORL modules with the terminal portion of the hub, is always kept at 7.0 psi atmospheric pressure.

The second section, the docking section, contains the docking ports and certain storage areas. Four ports are provided at the center of the OLF. Two are common to each other and diametrically opposite and provide docking ports for the spacecraft and LOX tankers. The other two ports, diametrically opposite and 90° radially from the other two ports, are for docking Apollo logistics spacecraft.

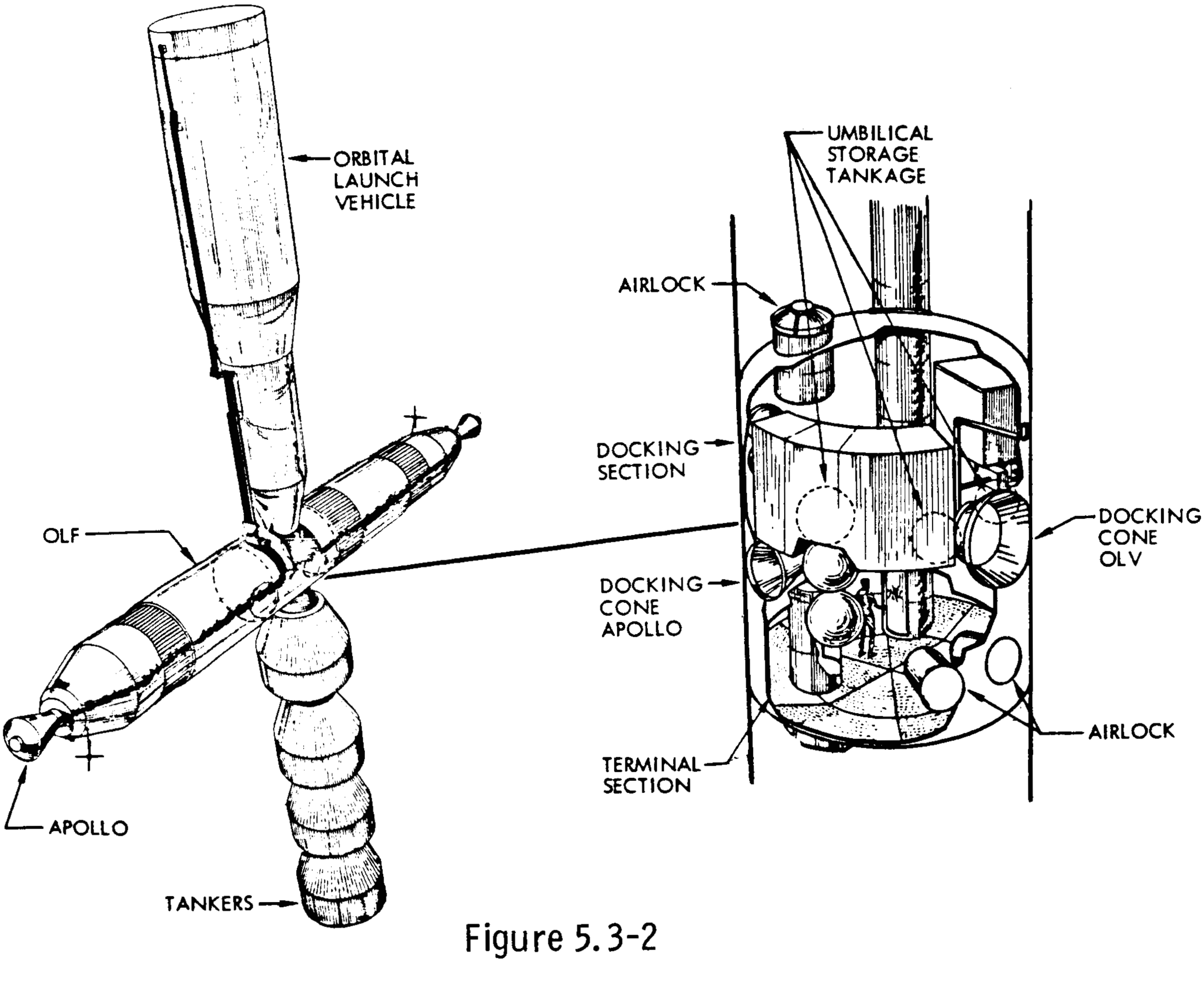


Figure 5.3-2

This section of the hub also contains a storage area in which expendables for servicing the spacecraft, as well as other supplies, tools, and expendables, are stored. An airlock provides access from this section to the experiment bay. Normally this section is maintained at 7.0 psi, but during certain operations it may be evacuated.

5.3.1.2 Elevator Subsystem. - The elevator system (Figure 5.3-3) provides a two-fold service. It not only carries personnel from either MORL to the hub terminal section, but the elevator tunnel and the hub also provide a pressurized route through the entire OLF from one MORL to the other. The elevator tubes are designed to retract into a short section at launch, and when the MORL modules are deployed after launch the tubes extend from the hub section to each MORL. The joints are sealed as part of the original checkout and assembly operations of the OLF.

A powered-lift cage, provided in each tubular section, transports personnel and supplies to and from either the MORL module or the hub section. The elevator terminates in an airlock at either MORL. A feature incorporated into the elevator shaft design is the cherry picker (or service ambulator) is supported from the elevator shaft and free to travel its length. This provides excellent mobility in the hangar bay, particularly during zero-g.

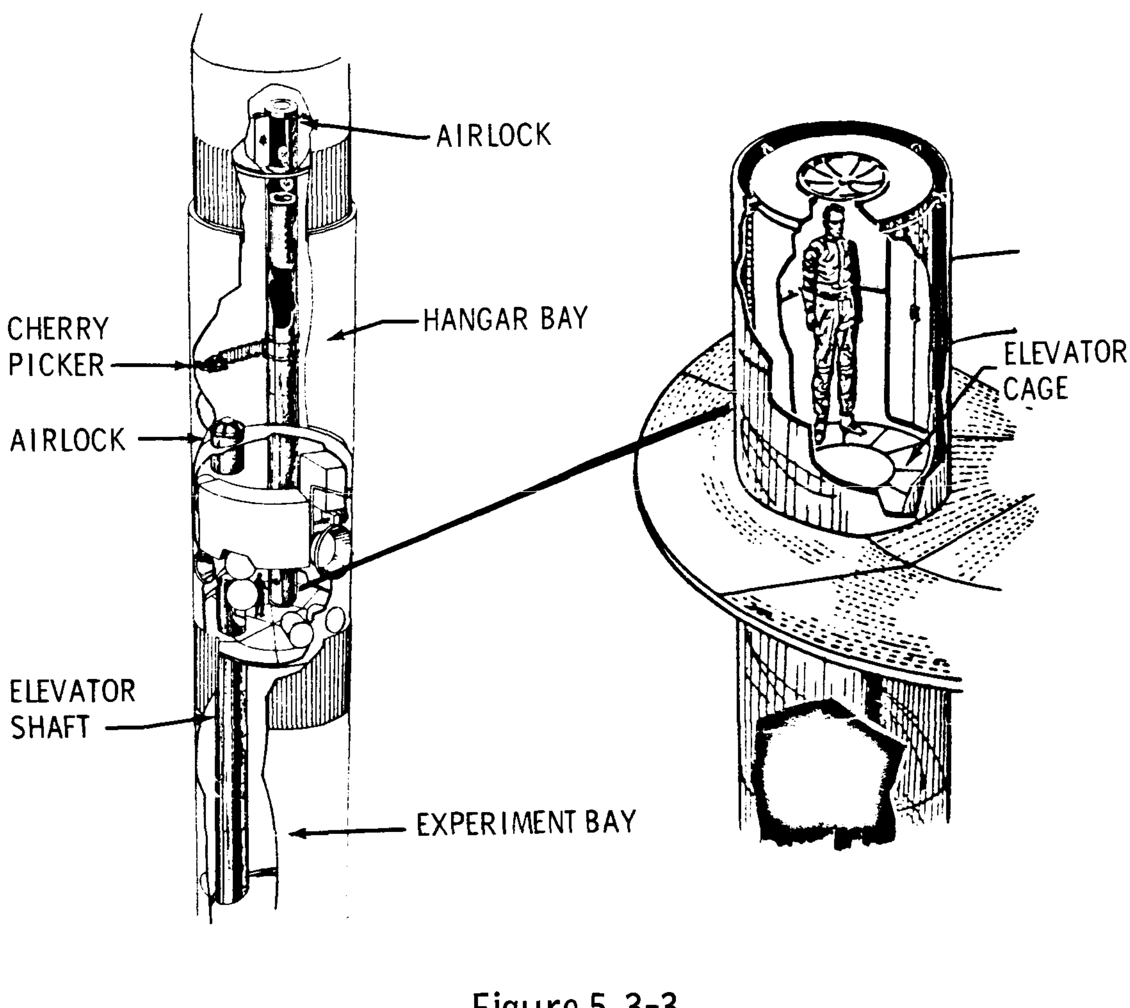


Figure 5.3-3

5.3.1.3 Umbilical Service Tower. - The umbilical service tower (Figure 5.3-4) is a major item of equipment for the OLF. The tower allows transfer of the LOX propellant from the tankers to the S-II stage of the orbital launch vehicle, transfer of other fluids and gasses, and co-axial and electrical cable connections between the spacecraft, S-II stage, and transtage of the orbital launch vehicle.

A major design problem of the umbilical, was allowing for the sway of the orbital launch vehicle with respect to the OLF, due to station keeping reactions, etc. To compensate for fore and aft sway, a series of linkages (Detail I, Figure 5.3-4) were built into the umbilical system. The fluid lines each have a swivel joint built into the line at each of the linkage axial centers. Lateral sway is compensated for by a series of bellows sections that allow lengthening or shortening of the different lines to allow for lateral angular displacement of the umbilical tower.

The linkages are radially driven at the joints by actuators during original deployment of the umbilical to provide for proper alignment of the umbilical plates with the matching pads on the vehicle itself. After mating and securing

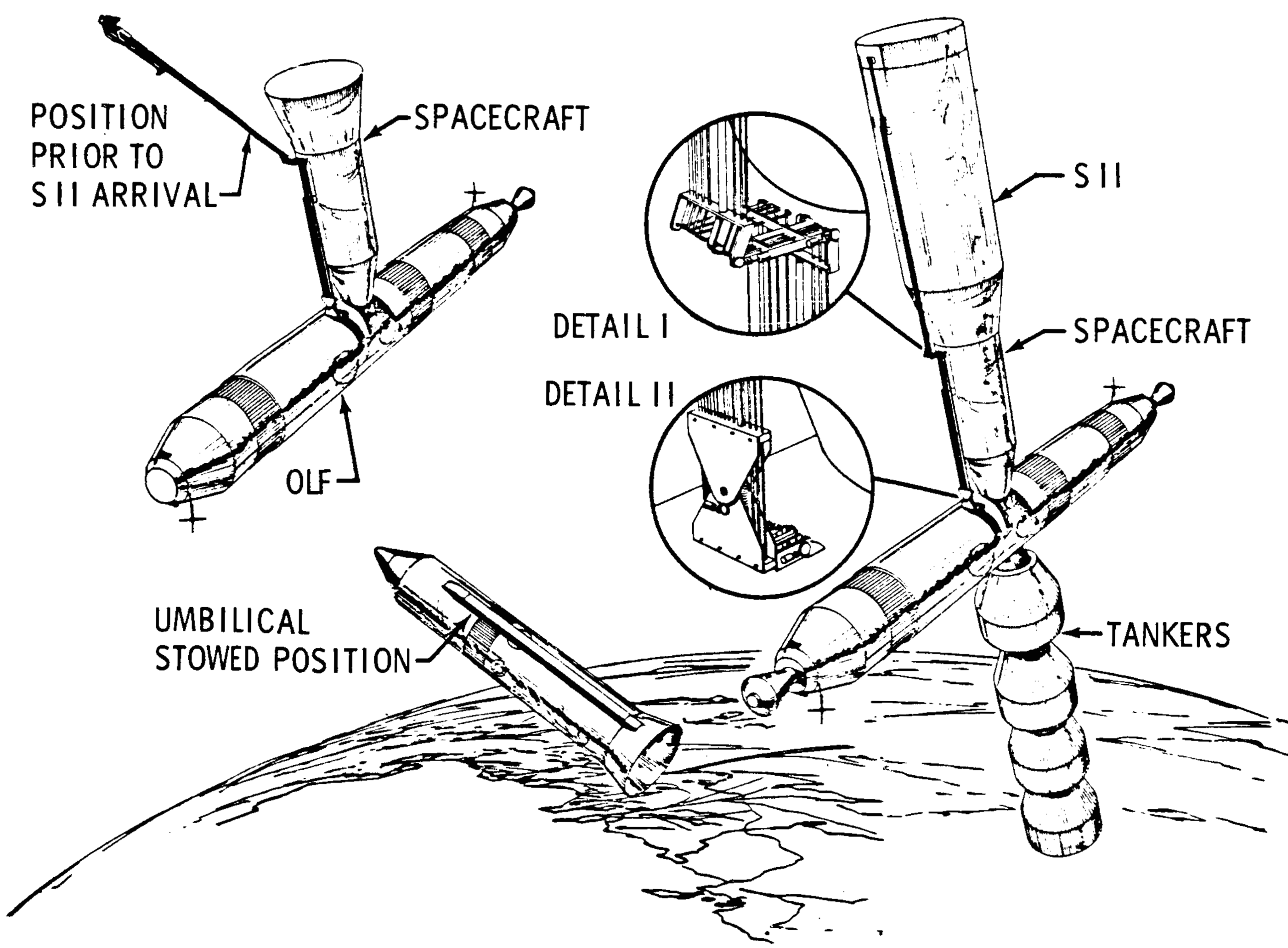


Figure 5.3-4

of the umbilicals, the drive motors are declutched to allow the umbilical to sway freely with the vehicle.

The various electrical and fluid lines are engaged by quick-coupling devices in the umbilical plates as the plates are brought together by manually tightening a series of toggle devices. During disengagement of the umbilical from the vehicle, however, the toggles are simultaneously and remotely disconnected and spring-actuated pins separate prior to orbital launch. The drive-motor clutches are then engaged and the umbilical rotated clear of the mission vehicle.

5.4 OLF On-Board Systems. - For all of the supporting studies of on-board systems for the OLF the following basic objectives were established:

(1) Utilization of MORL subsystems to maximum extent feasible;

(2) Design for simplification of service and maintenance and for optimum utilization of spare parts;

(3) Design for minimum extravehicular effort;

(4) Design redundancy into systems to ensure high probability of crew survival in emergency conditions.

With these objectives established, the on-board systems analysis consisted primarily of a review of MORL subsystems, in regard to the prescribed OLF functional requirements, to determine their applicability or modifications required to make them applicable. Also if any on-board system requirement could not be met by a MORL or modified MORL subsystem, an acceptable system concept was postulated and integrated into the overall design. General characteristics of each of the major subsystems on board the OLF are summarized below in terms of systems requirements and a short system design description.

5.4.1 Electrical Power System Requirements. - Three mission phases establishing a typical power load profile are:

(1) The launch phase, including orbital injection, for which the power requirement is 17 kwhr.

(2) The time, approximatley T + 6 to T + 50 hours, during which the OLF accomplishes crew transfer, separation, and deorbiting of the injection stage; extension of the MORL modules; routine inspection and repair; and activation of the primary power system. These extension and activation functions require approximately 128 kwhr.

(3) A routine operational phase, which includes three discrete functions of hangar pump down, data transmission, and OLV checkout and launch, requiring an average power capability of approximately 10.0 kW, with a peak load of 11.5 kW. Based on the average power requirements, 50% is AC(115/200) volts ± 2%, 3-phase 400-cps; 25% regulated DC(28.0 ± 0.5 volts); and 25% unregulated DC(24-31 volts).

5.4.2 Electrical Power System Design. - A study was conducted to evaluate solar-cell/battery and Isotope/Brayton power subsystems that would be compatible with the OLF configuration. Primary emphasis was placed on the weight comparison between the two systems. Figure 5.4-1 is a plot of electrical power system weight versus operating time in years. It is important to note that included within this weight parameter for the solar-cell/battery configuration are the penalties for control-moment gyros and reaction-control propellant necessary to orient and maintain stabilization required for Sun orientation. A fixed weight of 2050 pounds was allowed for control-moment gyros and an annual propellant consumption rate of 1,285 pounds was used for orbit keeping and attitude control, based on a solar cell panel area of 4,080 square feet. Station operation during the shadowed portion of the orbit requires an electrical load of 6.96 kwhr delivered to the useful buses, as derived from the electrical load profiles. Assuming a 0.8 regulator efficiency, 7.6 kwhr is required at the battery outlet. Assuming a 0.7-battery efficiency, 10.8 kwhr must be delivered to the battery for charging during the Sun-side operation. Also during Sun-side operation 12.8 kwhr of power must be delivered to the unregulated bus, with an average power requirement at the bus during one complete orbital cycle of 22.8 kW. For 5 years and 10% solar panel decay assumed per year, the initial solar panel output would be 38.5 kW.

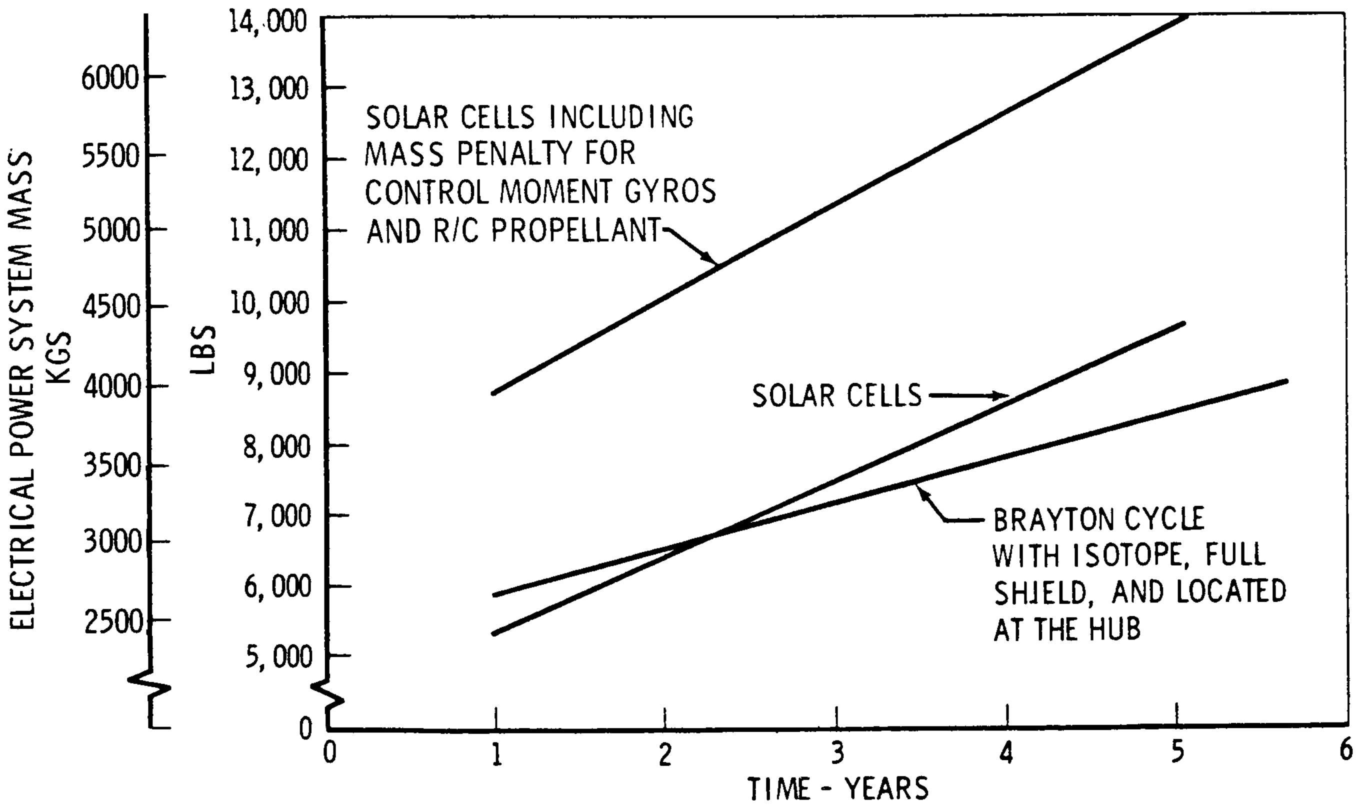


Figure 5.4-1

The Isotope/Brayton cycle system, as described in the MORL documentation, provides 11 kW of power and was readily adaptable to the weight trade studies. Component weights were considered to be the same, with primary weight adjustments being made for relocation of the isotope heat source and the addition of 1,665 pounds for OLF electrical distribution system equipment.

For the same shield thickness used on MORL, relocation of the isotope from the MORL skirt area to the OLF hub reduces the dose rate at the base of the crew quarters by a factor of 14. Based on integrated occupational times for various compartments, it is possible that the shield thickness may be reduced while maintaining the same dose rate.

Based primarily on the assumed availability of the Isotope/Brayton cycle with the MORL system and its potential advantages associated with a long OLF mission life, this system is currently recommended for the OLF. A functional diagram of the system is shown in Figure 5.4-2. Althouth not shown on the diagram, two 5.5 kW_e alternators provide power in parallel. Each rotating unit consists of a single-stage centrifugal compressor driven by a single-stage, radial-inflow turbine. The gas enters the centrifugal compressor, is compressed to the selected pressure, and flows through a recuperator where it absorbs waste heat from the

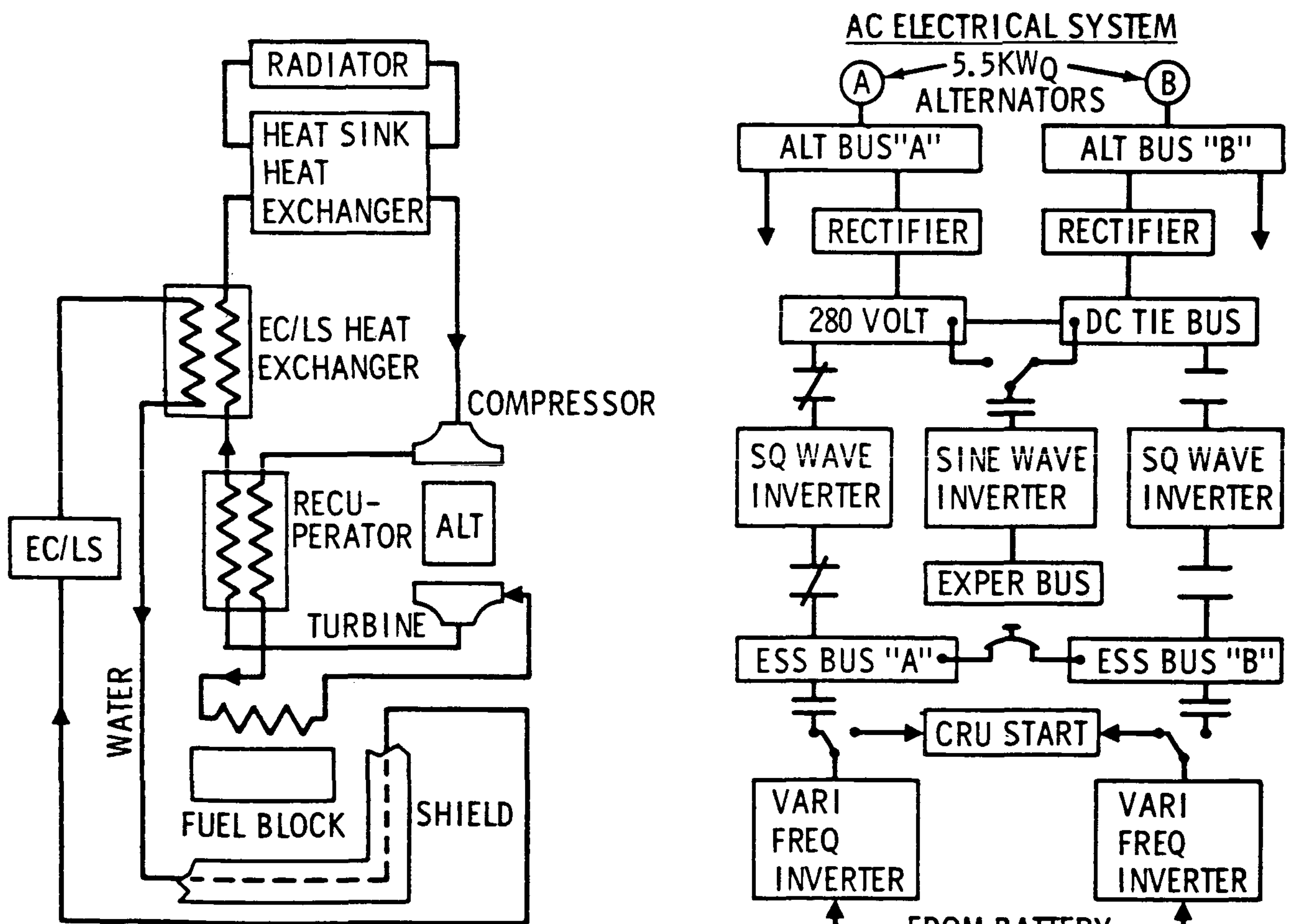


Figure 5.4-2

turbine exhaust. After leaving the recuparator, the argon gas enters the heat source heat exchanger, where isotope heat is transferred into the system by radiation. The gas then expands through a radial turbine and is exhausted to the recuperator, where waste heat is transferred to the compressor outlet gas. After leaving the recuperator, the gas enters an EC/LS heat exchanger, where heat is given up for life-support processes. The gas is further cooled by a space radiator and completes the cycle by reentering the compressor. In the event more heat is required by the EC/LS systems, heat can be obtained directly from the isotope heat source.

5.4.3 Guidance and Navigation Requirements. - The basic requirements of the OLF guidance and navigation system are provided by the MORL system. These include automatic and manual orbital determination and correction, rate signals for attitude stabilization, and periodic gyro drift corrections. Additional requirements are for an emergency rendezvous and docking control in case of a guidance-and-navigation system failure in the docking vehicle, and an autonomous navigation capability to support the OLV launchings and provide backup navigation in case of a communication failure.

5.4.4 Guidance Navigation Design. - Design of the MORL system allows automatic orbital corrections to be made based on ground tracking, orbital computations, and subsequent Earth-based commands. An alternate backup mode permits manual insertion of corrective maneuvers, based on data arrived from the on-board guidance and display systems.

For modes requiring precise attitude hold, periodic correction of the inertial rate integrating gyros (IRIGs) is necessary because they have a random drift rate. To accomplish this at a specified update point, the X and Y axes are controlled by the Sun sensors and the Z axis by the horizon scanners. Simultaneously, the IRIGs are switched to a rate mode and track the sensor portion commands. Ideally, the sensor inputs will go to null at the update point and rates about the vehicle axes will be essentially zero. At this time, the IRIGs switch back to the integrating mode.

Emergency rendezvous and docking control utilizes a radar interrogator aboard the OLF and a transponder in the docking vehicle. The radar supplies range, range-rate, elevation, and azimuth indications to the guidance computer. Calculations are then made and the velocity increments displayed for the required rendezvous. This information is transmitted via voice link frequencies to the docking vehicle.

An autonomous navigation backup system requires the addition of an inertial measuring unit, sextant, and scanning telescope; also, the horizon scanner must feed the digital computer. Computed orbital parameters are displayed and manual operation of the orbit-keeping thrusters then corrects the orbit.

5.4.5 Attitude Stabilization and Control Requirements. - The attitude stabilization and control system provides vernier orbit-injection control based on Earth commands automatically inserted into the control system; maintains attitude corrections during the OLV assembly and checkout, tanker docking, fuel transfer, and preignition separation; and allows orbital maneuvering and station keeping for correction of orbital decay. The long-term mission life requires station-keeping maneuvers during logistics resupply, during scientific experimentation, and to provide an artificial-gravity spin capability. Both automatic and manual control are required during all operations.

5.4.6 Attitude Stabilization and Control Design. - Adequate stabilization and control subsystem performance for the OLF mission can be achieved by using the MORL control system modified to delete the control moment gyros, relocating the reaction-control and orbit-keeping jets, and changing the control logic.

Basically, the system operates identically to the MORL with the exception that the MORL "belly-down" mode is unnecessary. A revised motor installation using existing MORL reaction motors provides sufficient thrust for attitude control and the maneuvering required for orbit keeping. Initial orbit injection and control could be performed by the orbit-keeping thrusters and reaction-control jets if necessary. The present concept, however, uses an injection stage for orbit injection and provides injection attitude control by reaction jets in the injection stage. Selected reaction control jets of the various vehicles docked to the OLF, will be controlled by the OLF stabilization and control system during OLO build-up (Figure 2.4-2) to provide good control authority of the relatively large disturbance torques.

Figure 5.4-3 is a plot of attitude control and stabilization system and propellant weight requirements versus days in orbit. From this it can be seen that during the orbital-launch operations, the selected nonstabilized mode of operation provides considerable advantage in propellant weight savings, as well as the savings in basic systems weight. It should be noted, however, that the non-stabilized mode curve does allow for the necessary attitude stabilization during navigation, docking, and orbital corrections.

5.4.7 Environmental Control System Requirements. - The environment of the hangar and experiment bays, the three hub compartments, and the elevator tubes (Figure 5.4-4) will also be maintained by the two MORL systems with minor modifications. Areas requiring modification are the air distribution system and possibly the atmospheric-contamination removal system. Although the biological contamination may be decreased, due to the reduced personnel loading during normal OLF operations, the increased area of structure and OLF equipment will increase the contamination through outgassing, vaporization of lubricants, etc. It is expected that a balance may be achieved without gross modification of the MORL systems. An accurate analysis of this condition would have to be made as part of a detailed facility design study in which the intended materials of exposed structure and equipment would be better identified.

5.4.8 Environmental Control System Design. - Figure 5.4-4 shows the basic additions to the MORL's environmental control system required to provide environmental control for the central areas of the OLF. Each MORL, in addition to controlling its own environment, will be capable of providing pressurization and atmospheric purification for the entire hub and elevator tubes and the bay volume (experiment or hangar) directly adjacent to the MORL. Bottled oxygen and nitrogen will be utilized for MORL extensions (0.5 psi) and for the initial pressurization (3.5 psi) forthe experiment and hangar bays, hub, and elevator tubes. Common ducting, with appropriate valving, is used between the two MORLs and the hub for final pressurization and control of the atmosphere of the hub compartments and elevator tubes. Following initial pressurization to 3.5 psi, the hub elevator terminal and

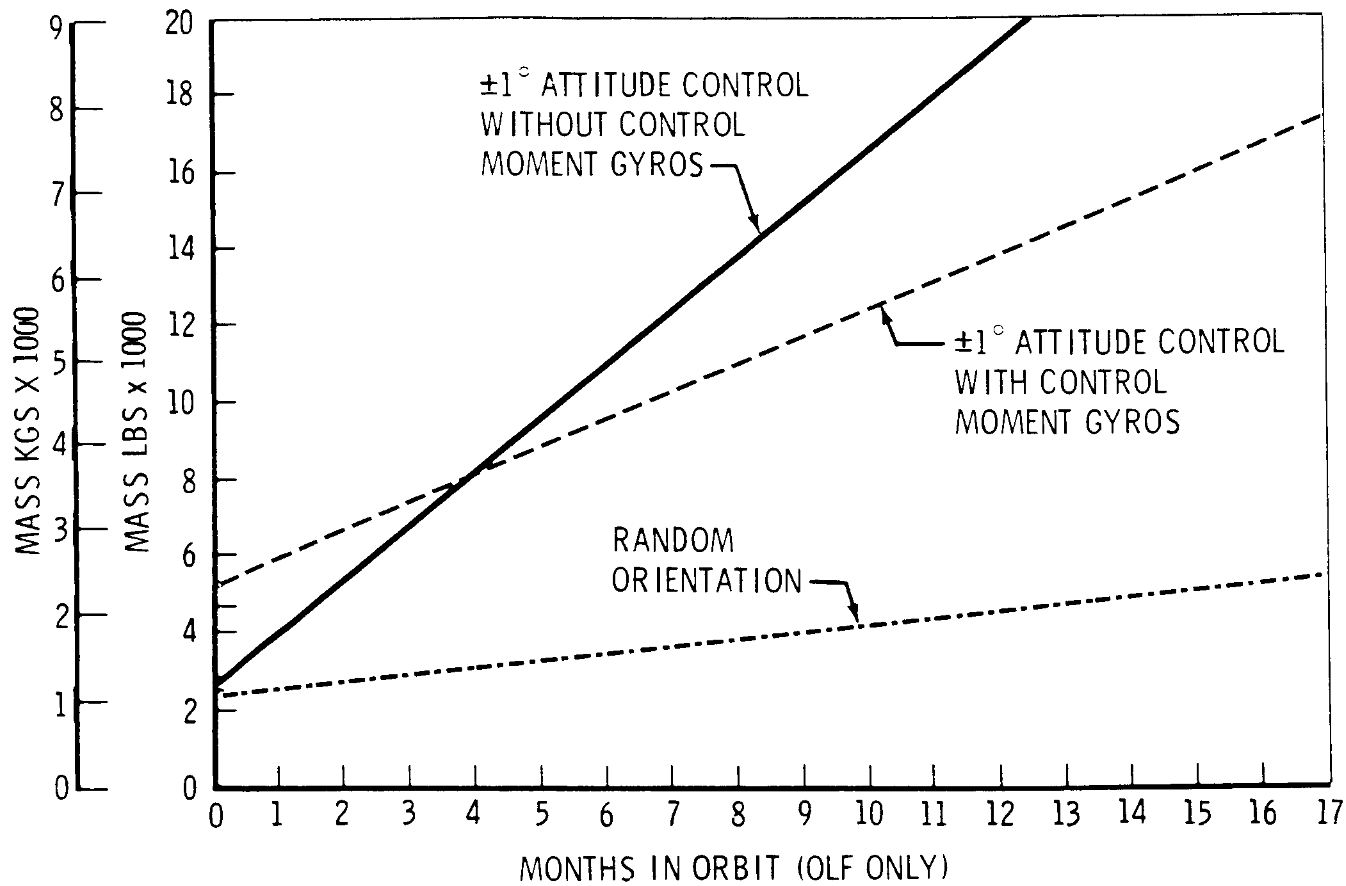


Figure 5.4-3

elevator tubes will be fully pressurized and maintained at 7.0 psi for shirtsleeve commuting between MORL modules and the hub. When it is found necessary to fully pressurize either the experiment or the hangar bay, one bay will be evacuated to provide pressurization for the other. This is accomplished by the transfer pumping system, after which the return vents of the pressurized bay are opened and circulation initiated. Atmospheric conditions of each compartment will be checked and monitored prior to and during their use to determine hazardous conditions of contamination, temperature, and pressure. Circulation and temperature control units are provided for each compartment. Umbilical life-support connections, provided in each compartment of the OLF, utilize the MORLs for atmospheric supply and purification as shown. The MORL environmental control system concept, utilizing oxygen regeneration, will be used because of its long-term economical advantages as shown in Figure 5.4-5. Based on the proposed Tapco-Bosch CO_2 reduction system, the environmental-control-system weight must be increased by approximately 200 lbs. and the radiator size increased by 230 square feet over a system not providing oxygen regeneration.

The Tapco-Bosch system schematic is shown in Figure 5.4-6. The Tapco reactor is a stainless-steel cylindrical shell that houses iron disk catalyst plates about

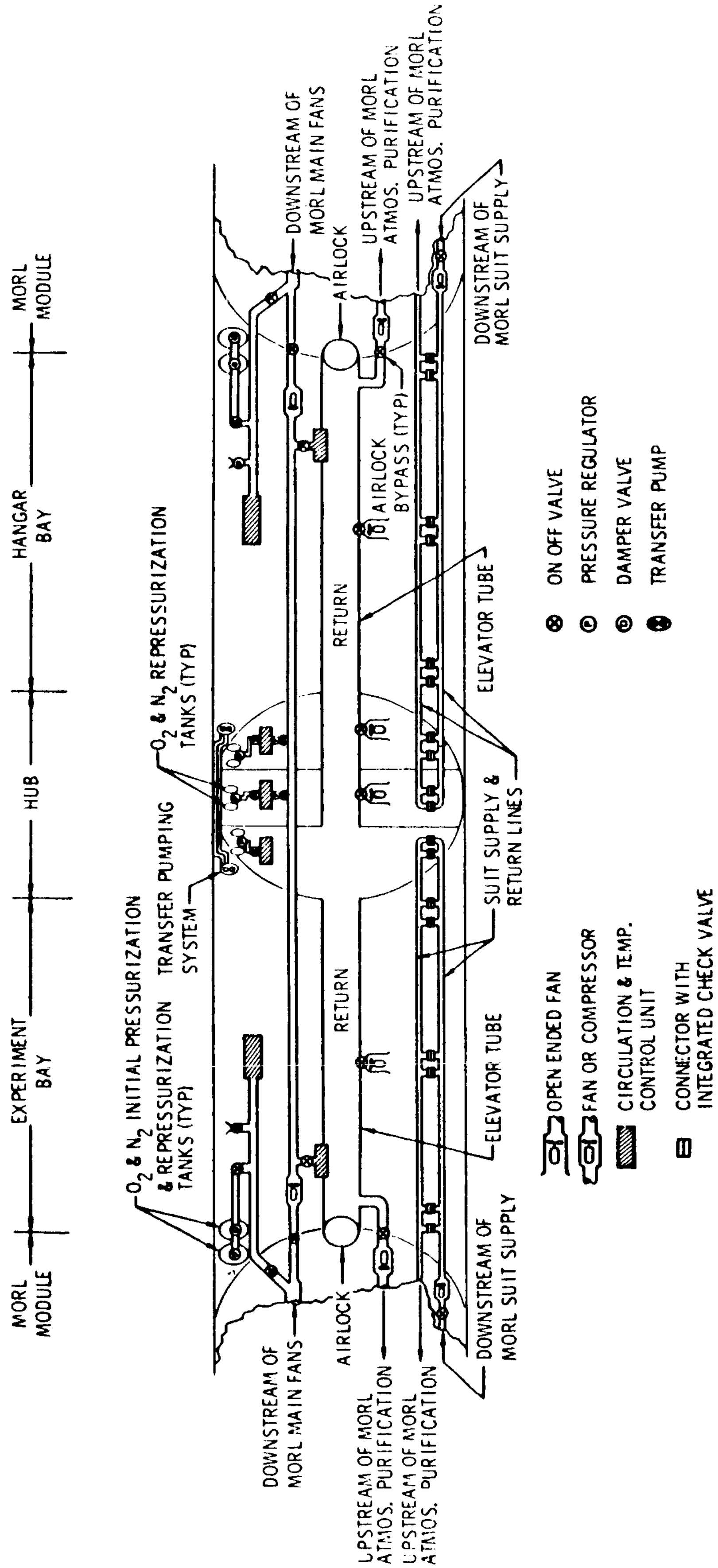

MORL MODULE
EXPERIMENT BAY
HUB
HANGAR BAY
MORL MODULE
O2 & N2 INITIAL PRESSURIZATION & REPRESSURIZATION TANKS (TYP)
TRANSFER PUMPING SYSTEM
O2 & N2 REPRESSURIZATION TANKS (TYP)
DOWNSTREAM OF MORL MAIN FANS
AIRLOCK
UPSTREAM OF MORL ATMOS. PURIFICATION
UPSTREAM OF MORL ATMOS. PURIFICATION
DOWNSTREAM OF MORL SUIT SUPPLY
RETURN
ELEVATOR TUBE
SUIT SUPPLY & RETURN LINES
RETURN
AIRLOCK BYPASS (TYP)
ELEVATOR TUBE
DOWNSTREAM OF MORL MAIN FANS
AIRLOCK
UPSTREAM OF MORL ATMOS. PURIFICATION
UPSTREAM OF MORL ATMOS. PURIFICATION
DOWNSTREAM OF MORL SUIT SUPPLY
OPEN ENDED FAN
FAN OR COMPRESSOR
CIRCULATION & TEMP. CONTROL UNIT
CONNECTOR WITH INTEGRATED CHECK VALVE
ON OFF VALVE
PRESSURE REGULATOR
DAMPER VALVE
TRANSFER PUMP

Figure 5.4-4

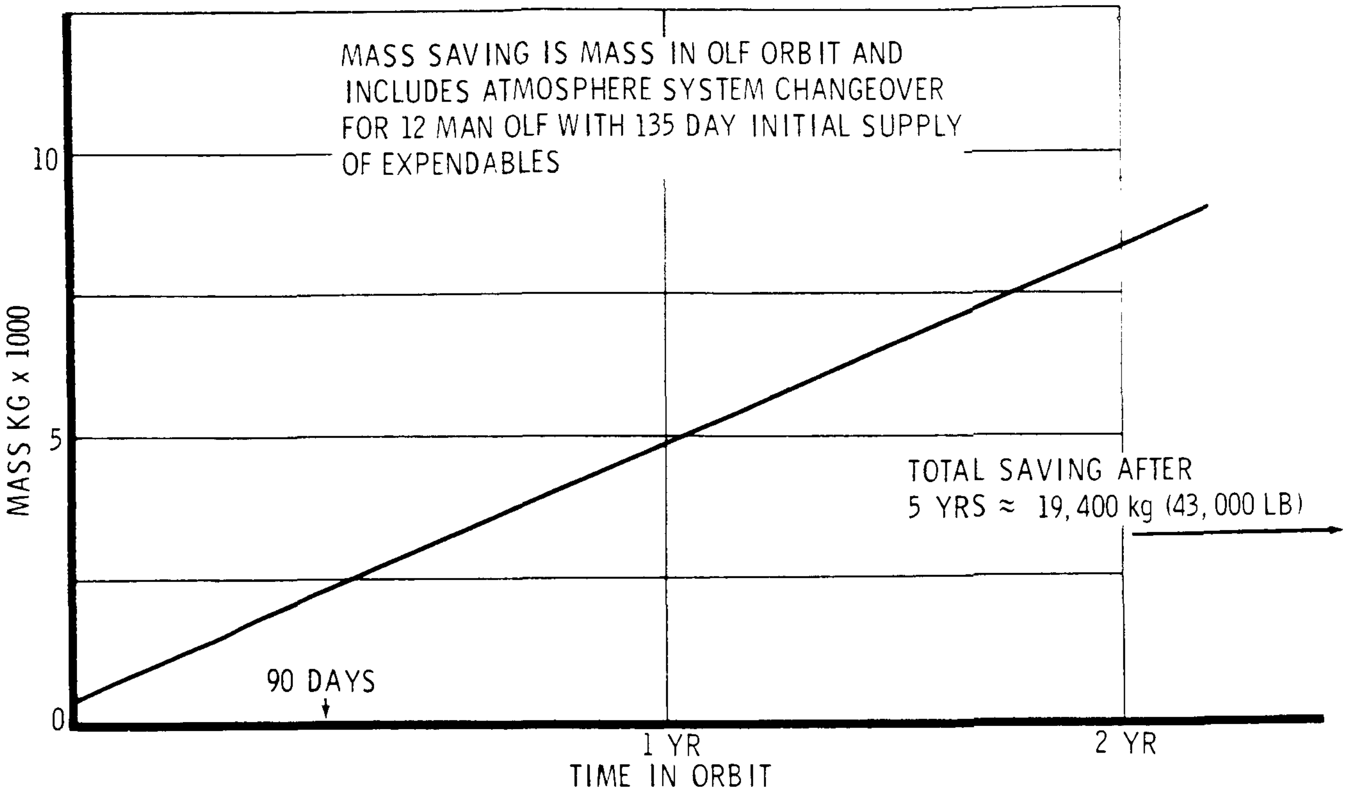


Figure 5.4-5

1/8 inch in thickness and about 1/2 inch apart. The disk assembly revolves at 1 rpm and carbon is removed from the disks by a set of scraper prongs extending from the side of the cylinder. The reactor is fed CO_2, H_2, and hot recycle gases. An electrical heater in the reactor provides additional heat to the entering gases to maintain a reaction temperature of 1200°F. From the center inlet manifold of the reactor chamber, the gases flow radially outward and carbon is deposited on the catalyst disks. The gas flow through the reactor picks up loosened carbon and transports it out of the reactor. The recycle gases, plus carbon particles, then pass to a stainless-steel filter. From the on-line stainless-steel filter, the reaction products flow through a diversion valve to either the regenerative heat exchanger or the recycle blower. Gas would be routed to the blower only if carbon transported by the gas flow through the reactor to the filters was not adequate.

The recycle gases passing from the diversion valve through the heat exchanger are cooled and then passed to the condenser separator. There they are cooled below the dew point of the contained water vapor by coolant from the heat rejection system. The condensed water vapor is separated from the non-condensable recycle gases by the action of a porous, metallic, capillary plate. The separated water passes to the

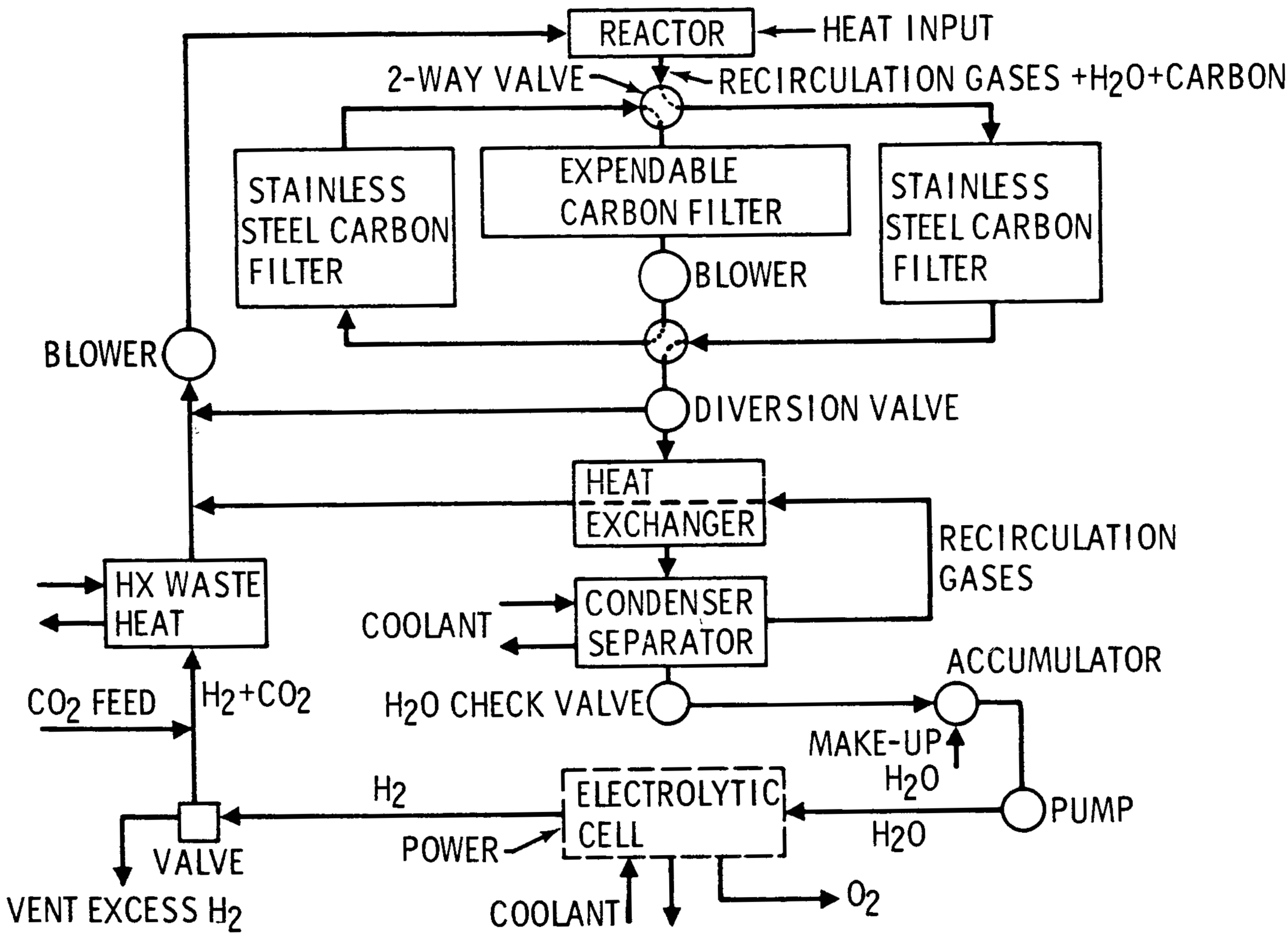


Figure 5.4-6

water electrolysis system and the cool recycle gases reenter the heat exchanger to cool the hot recycle gases from the reactor. From the heat exchanger, the recycle gases mix with the incoming CO_2 and H_2 and are then passed back to the reactor by means of the blower. Waste heat may be used to heat the incoming CO_2 and H_2 in order to conserve the electrical heater power otherwise required.

5.4.9 Crew Support - Requirements. - The crew support requirements include provision of all installed or transported personnel items and furnishing that facilitate the OLF duty for the crewmen. These include personal clothing and equipment and general (nonpersonal) facilities. Personal items are carried on board by each crewman. Food requirments are included with crew support description. The atmosphere and water requirements are included with the environmental control/life support system.

Of particular importance to design of all crew support items is the comfort of the crew, whose efficiency must be very high. Results of the recent Manned Environmental System Assessment (MESA) program at Boeing have indicated that food, noise, behavior of others and toilet facilities must receive special attention. An important requirement is that living conditions be made similar to Earth wherever possible. In every case where a choice between present items and advanced state-of-the-art items must be made, the crew familiarity and comfort should be the deciding factor.

5.4.10 Crew Support - Design. - The philosophy of the OLF design is that food, medication, recreational facilities, and similar equipment be useable by a large percentage of the possible crewmen. However in keeping with the recommendations for personal comfort and sense of well-being, large allowances have been made for individual and private equipment including clothing and leisure time provisions. Individually sized pressure suits are carried on-board by each crewman. Emergency suits, in three gross sizes only, are located for accessability at the hub and bay areas.

Facilities in the living quarters are similar to those of the present MORL design. Sleeping quarters have been analyzed, with acoustical panels and private leisure provisions included. Working stations are designed to minimize nearby personnel movement. Several types of restraint and locomotion devices are provided, including Velcro materials, hooking belts and foot or elbow cups.

A 2800 calorie diet is provided, consisting of a combination of frozen, dehydrated and freeze-dried food. The freeze-dried is recommended due to its better taste, texture and eye appeal, however astronaut choices will be considered in making up the menus. Personal hygiene is not based exclusively upon advanced state-of-the-art methods, but rather, familiar methods, such as a water stream shower, etc. Due to the active assembly type work, twelve man capacity, and six month stay period, extensive medical and dental facilities are provided, including a dental chair/operation table combination.

5.4.11 Checkout and Monitoring System Requirements. - The checkout requirements are shown in Figure 5.4-7.

5.4.12 Checkout and Monitoring System - Design. - The OLF checkout and monitor system block diagram reflects maximum use of the space checkout and launch equipment system concept developed by Lockheed to implement the equipment requirements for the OLF.

A detailed review of the checkout system as described in the Lockheed Final Report, Reference 4, clearly indicates that the functional capabilities and flexibility inherent in this system can be used to satisfy most of the OLF checkout and monitoring requirements. The OLF data requirements will not impose any design changes on the space checkout system configuration.

The major interface requirements with the checkout system will be associated with software programming. The integration of the checkout programs with the OLF program will require careful considerations with respect to timing for data access, evaluation, display, recording, and formatting for retransmission.

5.4.13 Data Management Requirements. - The checkout and launch equipment communication requirements, described by Lockheed and shown in Figure 5.4-8, were used as a baseline to develop the orbital data editing, ground-communication link description, and ground-network characteristics. These three signficant data-processing functions, in total, represent a very complex data management system and the information presented here is only a modest representation of this system.

SUBSYSTEM	MEASUREMENT TYPE			SAMPLING RATE		ACCURACY	DISPLAY
	ANALOG	DIGITAL	DISCRETE	LOW	HIGH		
ELECTRICAL POWER	38	0	5	3/MIN	1/SEC	2%	VOLTAGE — CURRENT SWITCH POSITIONS FREQUENCY
GUIDANCE & NAVIGATION	26	8	4	5/MIN	1/SEC	1%	AC — VOLTS STORAGE REGISTER
ATTITUDE CONTROL & STABILIZATION	5	3	8	1/MIN	1/SEC	2%	VOLTAGE (ANALOG) DISCRETE POSITIONS
ENVIRONMENTAL CONTROL	36	-	11	1/HOUR	1/SEC	2%	VOLTAGE (ANALOG) DISCRETE POSITIONS
LIFE SUPPORT	22	-	-	1/HOUR	1/SEC	2%	VOLTAGE (ANALOG)
STRUCTURES	18	-	-	1/HOUR	1/MIN	1%	VOLTAGE (ANALOG)
COMMUNICATIONS	17	-	-	3/MIN	1/SEC	1%	VOLTAGE — CURRENT DISCRETE POSITIONS (ANTENNA) FREQUENCY

Figure 5.4-7

However, basic guidelines were developed in this study that will permit future detailed system synthesis.

5.4.14 Data Management Design.- Figure 5.4-9 shows the relative magnitude of data that is measured and evaluated on board the OLF and the amount of data that is expected to be transmitted to Earth. For continuous data transmission to Earth, the rate is about 10^4 bits/sec. For once-per-orbit transmission, the rate is increased to 17×10^4 bits/sec. These bit rates are compatible with accepted communication system capabilities.

The orbital parameters of altitude, eccentricity, and inclination impose a number of constraints on the communications subsystem. The altitude of the OLF will determine the length of time that line-of-sight communications can be maintained with each ground station and the maximum range over which the communication links must operate.

To provide economic and reliable operation, the communications subsystem should be capable of working into established ground stations with operationally

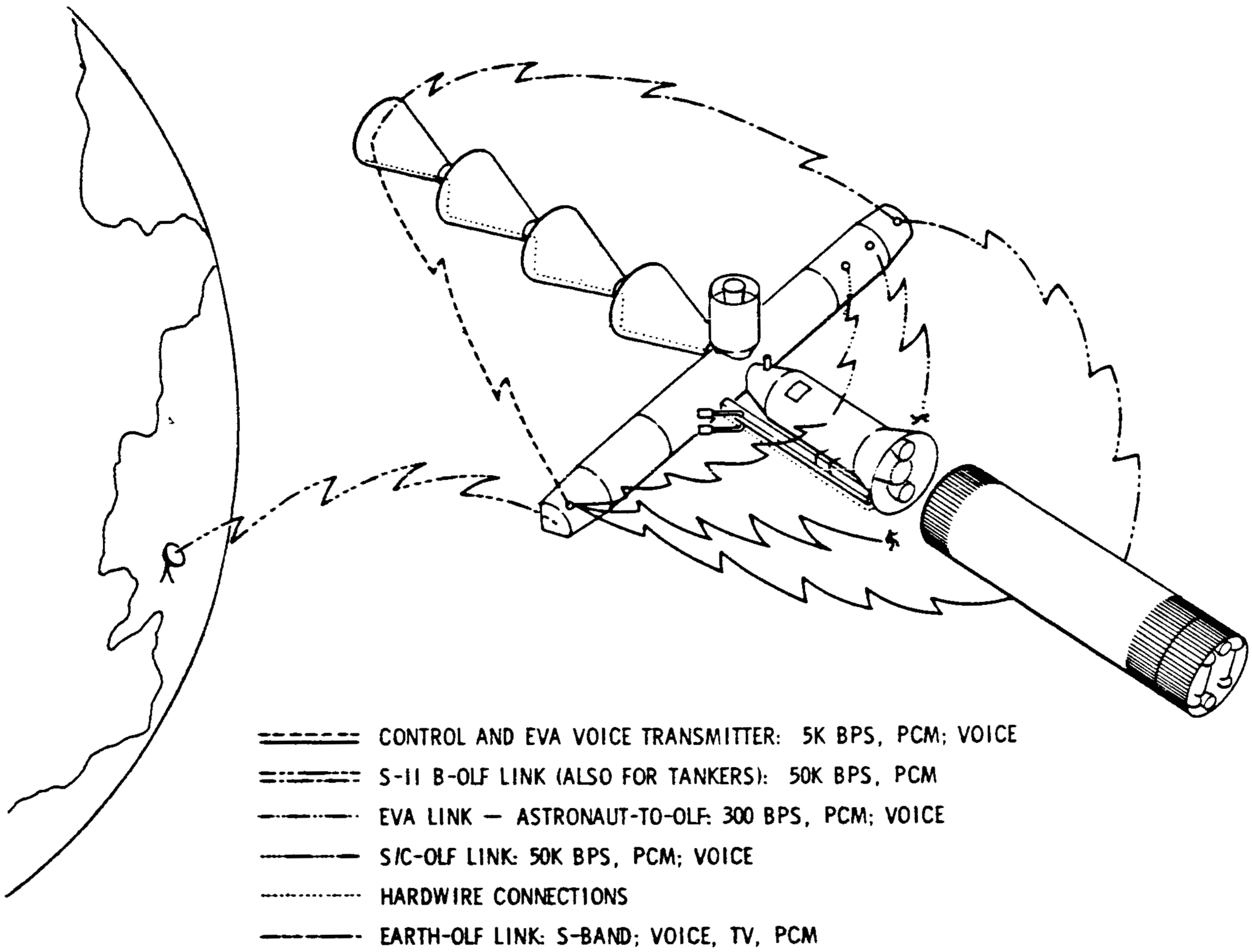


Figure 5.4-8

proven equipment. At the same time, care must be exercised to prevent saturating the ground facilities that will be used to provide support for the ever-increasing number of short-term operations. The cost of providing 24-hours per day manning of multiple, remotely located ground stations for the life time of an OLF makes it mandatory to optimize the number and location of these stations. Although the cost of keeping a tracking ship continuously on station may be extremely high, it may be feasible when in conjunction with other simultaneously occurring orbital programs.

For analysis purposes, the ground track for the OLF's circular orbit of 288 nautical miles altitude and an inclination of 38°, with respect to the equator, has been made. Assuming that reliable communications can be provided only for elevation angles of greater than 5° (which corresponds to a communication radius of 1200 nautical miles), 36 land- and ship-based ground station will be required to provide nearly continuous coverage while once-per-day orbit contact can be accomplished, using only three ground stations. Three stations located in the western hemisphere will provide reliable, once-per-orbit communications at approximately the same time in each orbit. Selected representative ground sites are the Manned Space Flight Network Stations at Quinto Ecuador and Antofagasta Chile.

• TOTAL DATA REQUIREMENTS	OLF EARTH DATA TRANSMISSION
• CONTROL (EXCITATION) OLV — 743 OLF — 161	ASSUME 3 : 1 DATA EDITING
• MEASUREMENT (RESPONSE) OLV — 1350 OLF — 205	FOR NEARLY CONTINUOUS DATA TRANSMISSION $\frac{50 \times 10^6 \text{ BITS}}{54 \times 10^2 \text{ SEC}} \approx 10^4 \frac{\text{BITS}}{\text{SEC}}$
• TEST TIME 100 MINUTES (MAX)	FOR ONCE PER ORBIT PATH TRANSMISSION
• BITS/SEC 50^K (MAX)	$\frac{50 \times 10^6 \text{ BITS}}{3 \times 10^2 \text{ SEC}} \approx 17 \times 10^4 \frac{\text{BITS}}{\text{SEC}}$
$5 \times 10^4 \frac{\text{BITS}}{\text{SEC}} \times \frac{6 \times 10^3}{2} \text{ SEC} = 150 \times 10^6 \text{ BITS}$	

Figure 5.4-9

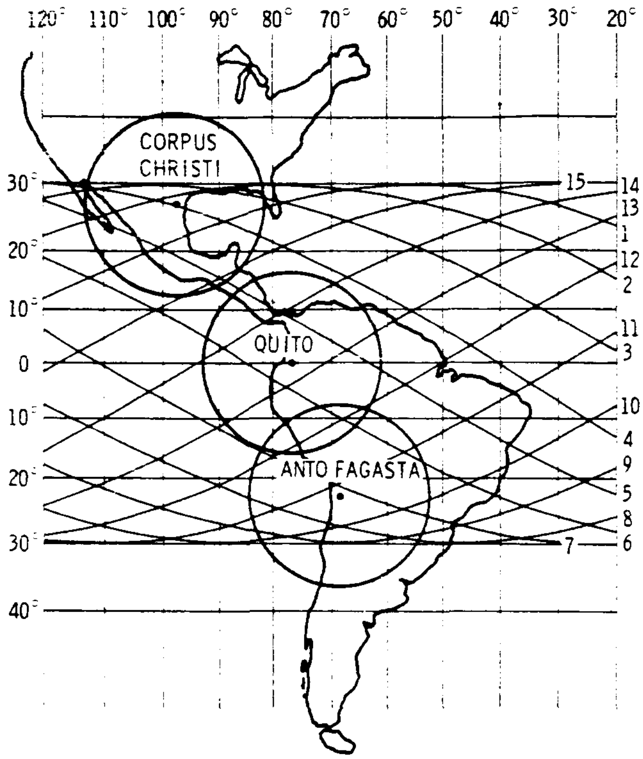
A total of 127.4 minutes per day of communication time is available, with the minimum time for any orbit being 5.1 minutes.

The stations at Corpus Christi, Texas; Quito, Ecuador; and Antofagasta, Chile, (Figure 5.4-10) provide optimum orbital coverage for the once-per-orbit concept. Wide band, microwave transmission facilities exist between the Corpus Christi and Manned Spaceflight Center (MSC) in Houston (expected locations of the Mission Control Center (MCC). Full duplex, 60 word-per-minute-teletype radio circuits, using the Canal Zone as a relay point, are available between Quinto and Antofagasta and Washington, D.C.; it is expected that these are, or will be tied directly into MSC. Buffering and format conversion would be required to transmit video data received at these stations to the MCC.

At present, the Quito and Antofagasta stations are not equipped to support a manned mission such as OLF. This deficiency should be corrected by 1975 because of the utility that can be achieved by using these stations to support OLF.

5.5 Advanced OLF Concepts. - The objective of this part of the study was to investigate the evolutionary requirements for providing orbital facilities capable

REPRESENTATIVE SITES



FACILITY CHARACTERISTICS

REMOTE SITES

UNIFIED "S" BAND COMMUNICATION EQUIPMENT
TWO WAY DOPPLER TRACKING & RANGING
ON-SITE DATA PROCESSING
- FLIGHT TELEMETRY
- FLIGHT COMMAND
- FORMAT CONVERSION & DATA EDITING FOR RETRANSMISSION

COMMUNICATION SYSTEM

3 FULL DUPLEX TTY	(30 bps)
1 HIGH SPEED DATA	(600 - 1200 bps)
1 VOICE	

FREQUENCY & TIME STANDARDS
DATA RECORDING
- FR 800
- FR 1200
- OSCILLOGRAPHS

MISSION CONTROL CENTER

DATA PROCESSING SYSTEM
- CENTRAL COMPUTING COMPLEX
- TELEMETRY PROCESSING SYSTEM
- DATA CONTROL & DISPLAY

COMMUNICATIONS SYSTEM

6 FULL DUPLEX TTY	(30 bps)
4 VOICE	
3 HIGH SPEED DATA	(600 - 1200 bps)
1 WIDE BAND ANALOG DATA CHANNEL	

Figure 5.4-10

of supporting such advanced missions as the Mars landing mission or the Lunar ferry mission. Although this effort was a relatively small part of the overall OLF study, the influence of advanced missions support requirements on the initial OLF concept evaluations are significant. In designing and developing such large and expensive systems as the OLF, the inherent growth potential designed into a concept is an important factor.

Once the orbital support requirements for the advanced missions were established, the main effort in this study was directed at comparing these with the support requirements imposed upon the initial OLF (for supporting the Mars/Venus flyby mission) and determining the modifications required. By study directive the advanced missions were postulated to utilize a different mode of operation wherein the tankers and the mission vehicle were not docked to the OLF as was the case in the initial OLF operating mode. Figure 5.5-1 summarizes the manned planetary and lunar ferry mission requirements in terms of parameters of most concern to the OLF design. Note that three mission concepts were tabulated for the Mars-landing mission. This is because of significant variations between the studies accomplished to date. The parameters associated with the lunar ferry mission can more accurately be determined at this time, therefore only one lunar ferry mission is shown. The parameters for

Figure 5.5-1 MANNED PLANETARY AND LUNAR MISSION REQUIREMENTS

ITEM	MARS FLYBY	1 DOUGLAS MARS LANDING	2 MARTIN MARS LANDING	3 G. D. MARS LANDING	4 LUNAR FERRY
CREW (Max)	13 for 11 days*	16 for 30 days	15 for 20 days	16 for 30 days	10 continuous
SPARES (for OLV)	1433 kg (3160 lbs)	1820 kg (4000 lbs)	1270 kg (2800 lbs)	2500 kg (5500 lbs)	354 kg (799 lbs)
DOCKING PORTS:					
Logistic Spacecraft	4	4	4	4	4
Lox Tankers	1	0	0	0	0
Orbital Launch Vehicle	1	0	0	0	0
OSE:					
RMU	2	2	0	2	2
AMU	4	8	4	5	4
OSAV	0	0	0	0	1
CHECKOUT EQUIPMENT - OLV Support	182 kg (400 lbs)	915 kg (2015 lbs)	734 kg (1615 lbs)	1115 kg (2450 lbs)	536 kg (1180 lbs)

Figure 5.5-1 MANNED PLANETARY AND LUNAR MISSION REQUIREMENTS - Cont.)

ITEM	MARS FLYBY	[1] DOUGLAS MARS LANDING	[2] MARTIN MARS LANDING	[3] G. D. MARS LANDING	[4] LUNAR FERRY
POWER - OLV SUPPORT	1.4 kw	2.2 kw	1.86 kw	2.3 kw	1.48 kw
TOOLS - OLV SUPPORT	34 kg (75 lbs)	181 kg (400 lbs)	150 kg (330 lbs)	191 kg (420 lbs)	118 kg (260 lbs)
HANGAR	1.4 M^3** (47 ft^3)	2.0 M^3 (67 ft^3)	.6 M^3 (20 ft^3)	1.5 M^3 (52 ft^3)	114 M^3 (4000 ft^3)
HANGAR MECHANISMS					
RMU	1	1	1	1	1
OSAV	0	0	0	0	1
COLD FLOW TEST FACILITY	0	0	0	0	1

* Capability of 12 full time or 18 for 14 days.
** Available space 437 M^3 (15,400 ft^3) part of which is needed for Apollo service periodically.

[1] Recommended concept of Ref 5

[2] Recommended concept of Ref 6

[3] Recommended concept of Ref 7

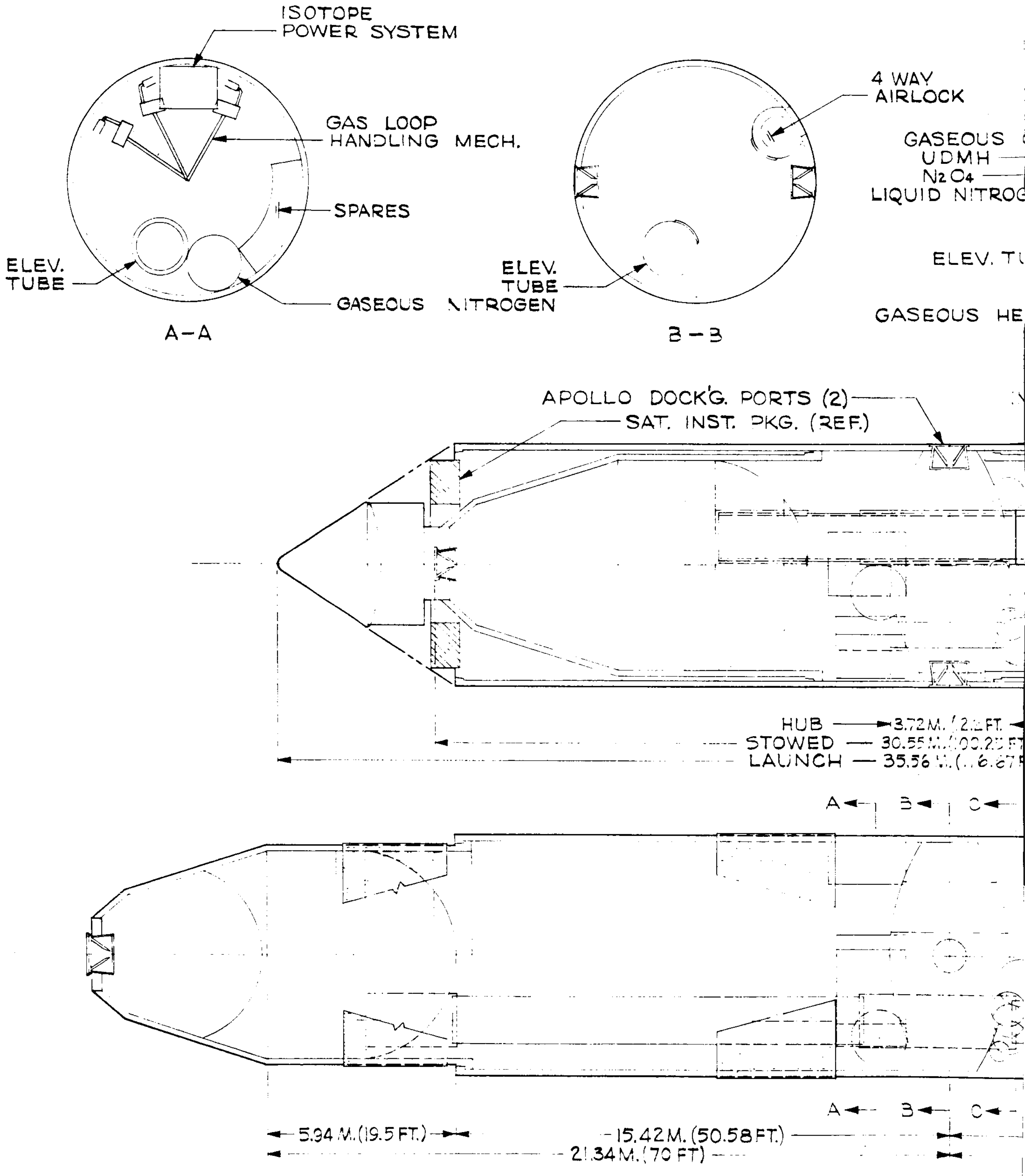
[4] Recommended concept of Ref 8

the Mars/Venus flyby mission (the baseline mission for the initial OLF) are also presented for comparison purposes.

5.5.1 Mars Landing Mission OLF. - In comparing the requirements of the baseline mission with the composite demands of the three Mars-landing missions, it became apparent that no major design changes were required. Although the on-board crew support requirements are slightly greater in the number of people but less in duration, the initial OLF systems are considered adaptable. The storage space available in the initial OLF is considered very adequate to accommodate the storage of added spares, OSE (AMUs) and propellants, checkout equipment and tools. The four Apollo docking ports of the initial OLF meet the requirements for this mission's support as do the other OLF mechanisms. Although the initial OLF power system appears marginal for this mission, uprating of the power level appears feasible. Because of the "undocked" mode of operation, the service umbilical tower and large OLV and tanker docking ports were eliminated from the OLF. The primary changes in the initial OLF to arrive at the concept, developed to support this mission, are shown in Figure 5.5-2. They consist of: a shorter launch configuration, lengthened structural cylinder, relocation of nuclear power plant to the experiment bay from the hub section, and slight changes in one MORL module's skirt length.

5.5.2 Reusable Lunar Ferry OLF. - In reviewing the lunar-ferry-mission support requirements imposed upon the OLF, it was found that in most cases, the requirements were less demanding than those of the Mars-landing mission and were generally within the initial OLF capabilities. However, two new requirements did appear for the lunar-ferry-mission support. The lunar ferry vehicle's use of a nuclear-heat-exchanger propulsion system dictates the need for an orbital support assembly vehicle (OSAV) and for cold-flow test facilities on board the OLF for checkout of replacement engines. The added hangar space for an OSAV is available in the initial OLF, and stowage mechanisms can readily be adapted to handle the OSAV. The cold-flow test requirements offer a problem not necessarily in providing test equipment and fluid storage, but more in the actual performance of the tests in such a manner as to not subject the OLF to large perturbing thrusts that would have to be either nullified or corrected. Test-data-management requirements for these tests can adequately be met by the initial OLF's capability. A detailed design study would be required to resolve the cold-flow test problems, but meeting the requirements appears reasonable.

5.5.3 Composite Design. - In general, the requirements imposed upon the OLF by the advanced OLO missions can be met with relatively minor modifications of the basic concept recommended for the initial OLF. It would, therefore, be advantageous in future studies to consider such applications in the initial OLF concept and adjust the design as may be economically and technologically feasible.



NOTE - SEE DWG. 25-53675 (ORBITAL LAUNCH FACILITY -

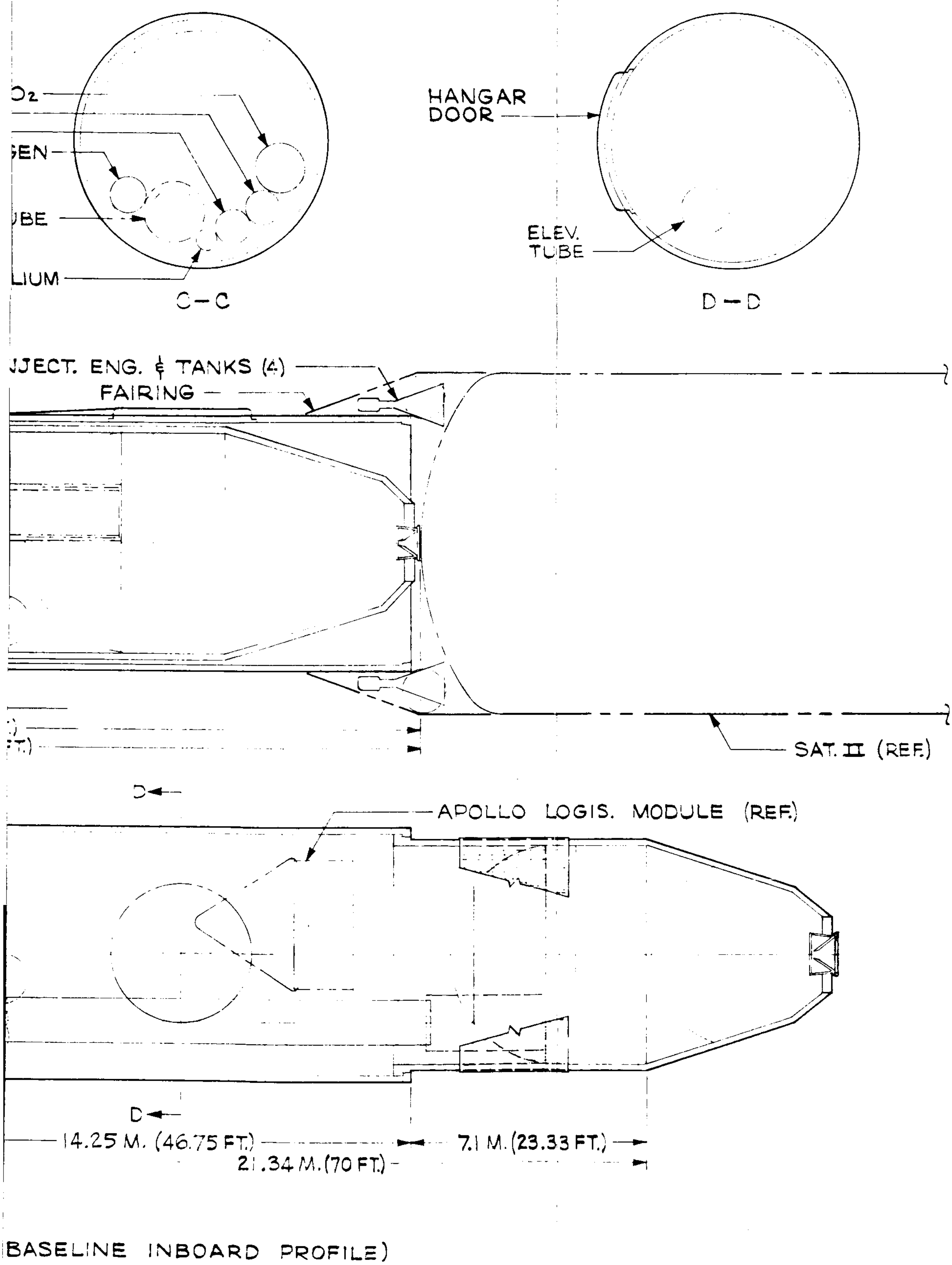


Figure 5.5-2: ADVANCED ORBITAL LAUNCH FACILITY — INBD PROFILE

6.0 SPECIAL STUDIES

Three areas of special interest to the OLF design are: (1) artificial gravity provisions in the OLF design; (2) R&D and scientific experimentation on board the OLF, and (3) definition of experimentation required for the OLF development that should be accomplished in orbital research laboratories. These areas of interest, made subjects of special studies in the OLF study, are summarized below.

6.1 Gravitational Level Analysis. - The purpose of this study was to determine the operational activities, if any, that might dictate the need for artificial gravity on board the OLF. The study of zero-gravity effects on man in the orbital environment has been planned and has already been initiated. Therefore, no attempt was intended in this study to predict the psycophysiological effects of zero gravity on man. As a secondary objective the artificial gravity requirements for performing R&D and scientific experiments on-board the OLF were to be evaluated and provisions for them recommended.

6.1.1 Approach. - This study was divided into analyses of the performance of personnel activities and systems operations. The various activities expected on-board the OLF were analyzed to determine the effects of artificial gravity, or the lack of it, on the performance of those activities. In cases where the lack of artificial gravity appeared necessary, an estimated gravity level was to be provided and/or substitute suggested. A similar analysis for the on-board OLF systems was to determining the effects of gravity, or lack of gravity, on the systems operation. A desired level of artificial gravity was estimated where necessary or a substitute suggested. R&D scientific experiments that could be expected to be performed on-board the OLF were also to be analyzed to determine their gravitational level requirements.

6.1.2 Results. - In the analysis of personnel performance in expected OLF activities under artificial and zero-gravity conditions, an extensive review of previous and current studies in zero-gravity effects was necessary. The effects of body movements, methods of locomotion, and applications of forces in a tethered or untethered condition in zero gravity and in the artificial-gravity condition were reviewed, within the framework of the limited knowledge presently available, to establish a basis for evaluating the expected OLF intra- and extravehicular activities. Generally speaking the rotation of the OLF for artificial gravity was found to severely complicate most of the extravehicular activities and would actually make certain activities impossible without gross modification of some of the OLF systems. The docking of other vehicles to the OLF, for example, would require either stopping the OLF rotation or providing a nonrotating docking hub. Periodic rotational operation of the OLF would necessitate restraining design features for all equipment, personnel, tools, stores, etc., and would complicate the facility operations in the transition between rotating and nonrotating modes of operation. Intravehicular activities at radial distances greater than 15.5m (50 ft.) were found to be simplified somewhat by the rotational operation, but in areas at short radial distances from the facility's rotational center the Coriolis effects significantly hinder personnel activities. Detailed analyses of the OLF activities with respect to gravity requirements are presented in Section 6.1 of the detailed technical report and describe the activity, frequency expected for each activity, the desired gravity level if any, and the evaluation results.

Similar detailed charts of the systems evaluations giving system description, desired gravity level, and evaluation results are given in the same section of the detailed technical report. Generally, the electrical power, checkout, and monitoring and display systems of the OLF would not be operationally affected by either the presence or absence of artificial gravity. However, the maintenance of these systems in a zero-gravity environment may require special provisions to prevent contamination and eventual degradated performance or complete malfunction of those systems. Guidance and navigation, communications, and data-management systems require a stable platform for continuous fixed alignment. This presents problems in a rotating facility, which then involve the stabilization and attitude control systems. The environmental control and life-support systems operations would greatly be simplified by artificial gravity, whereas the OLF structures and mechanisms would generally be penalized by the rotational mode.

Figure 6.1-1 summarizes the conclusions of the evaluations of OLF systems and activities in regards to artificial gravity. As a result of these evaluations, the activities and systems are classified under one of three groups: Group I -- not affected by gravity level; Group II -- complicated by artificial gravity; and Group III -- simplified by artificial gravity.

The investigation of artificial gravity requirements for possible R&D scientific experiments that might be accomplished on board the OLF consisted of a cursory review of applicable experiments (analyzed in Paragraph 6.2) for which some evaluation could be made with respect to gravity requirements and classification of those experiments into five categories. Of the 67 experiments included in this analysis, 46% fell in the category of "definitely requiring no artificial gravity", 31% fell in the category of "not affected by presence or absence of artificial gravity", 12% "required rotation", 6% were ones whose "requirements could not be established one way or another at this time", and 5% fell into the category of "could be accomplished more easily without aritificial gravity".

The results of the gravitational level analyses were far from conclusive, although a better insight was gained into what the problems may be and where they may be encountered in attempting to provide a rotational facility for artificial gravity. At this point it is felt that unless the psycophysiological effects of extended weightlessness on man dictate a need for artificial gravity fewer problems would be encountered in the development and operation of a zero-gravity facility.

Although the recommended OLF concept is adaptable for either the zero-gravity or rotational mode of operation, an adaptation of the general concept for strictly zero-gravity operation is shown in Figure 6.1-2. This concept simplifies the orbital assembly and checkout operations because extension of the MORL modules are not required. It does not have the hangar or experiment bay volumes provided by the recommended concept and must use the addition of docked modules as its growth mechanism. In this study only a cursory analysis and comparison of these concepts could be made. More detailed studies in this vein could be profitable.

FIGURE 6.1-1 ARTIFICIAL GRAVITY EFFECTS ON OLF SYSTEMS & ACTIVITIES

GROUP CLASSIFICATION	SYSTEMS	ACTIVITIES Extravehicular	ACTIVITIES Shirtsleeve
Group I Not Affected By Gravity Level	. Electrical Power . Checkout & Monitoring . Display	. Extension of MORLs . LOX Transfer	. Assembly of OLF Subsystems
Group II Complicated By Artificial Gravity	. Guidance & Navigation . Attitude Control & Stabilization . Communications & Data Management	. Separation & docking of Apollo CM . Deorbit of Apollo CM fairing & Injection stage . Scheduled Maintenance . Unscheduled Maintenance . OSE Operation . Docking Operations . Boom Extension . OLV & Fuel Tanker Checkout . OLV Separation	. None
Group III Simplified By Artificial Gravity	. Environmental Control . Life Support	. None	. Checkout of OLF Subsystems . Routine Operations . Housekeeping . Nutrition . Leisure . Personal Hygiene . Scheduled Maintenance . Unscheduled Maintenance

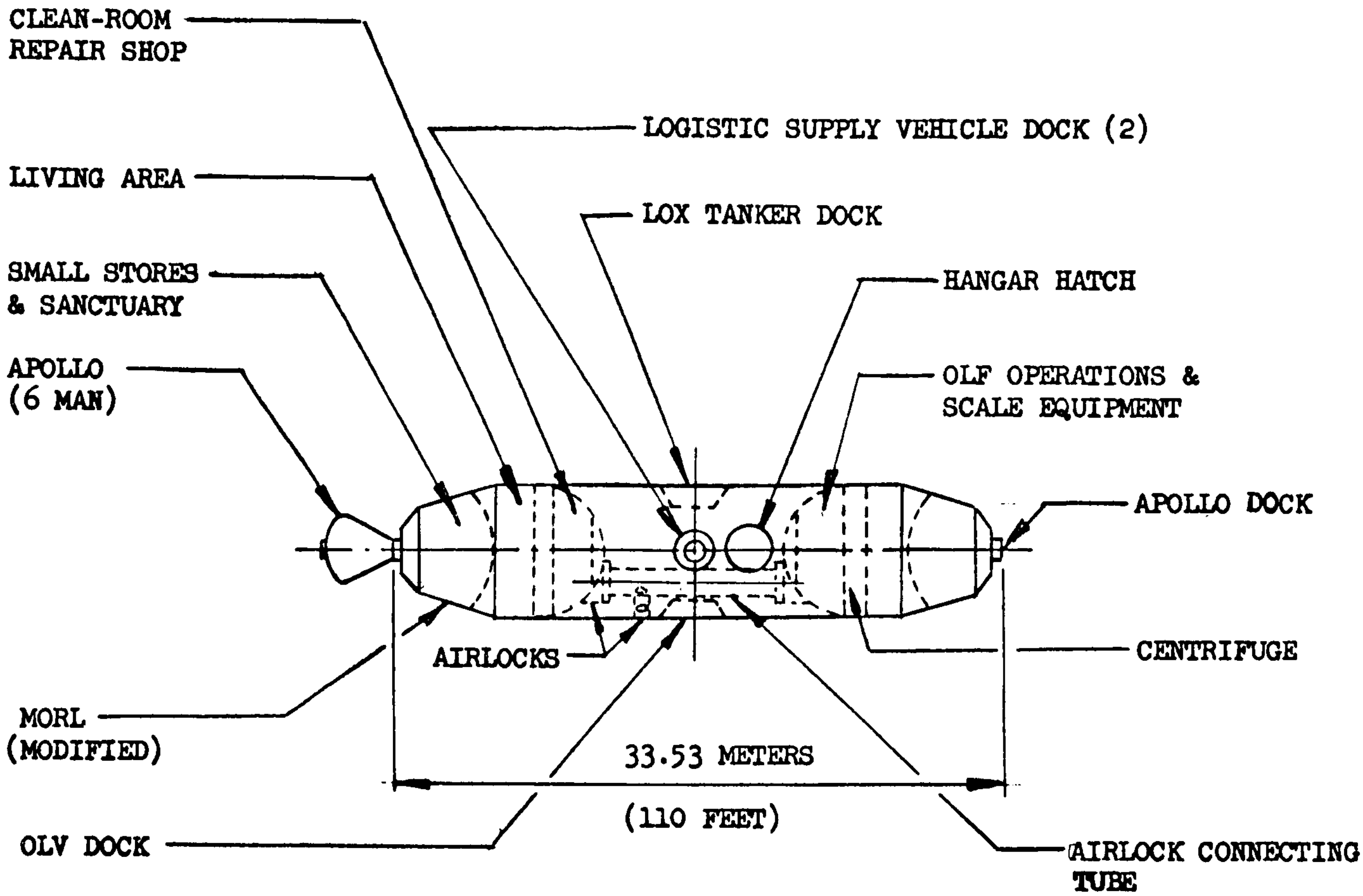


Figure 6.1-2

A brief study was made of the RDT&E plan and costs involved in the zero-gravity concept. Compared to the initial OLF, the zero-gravity concept is a less complex design. The elimination of the requirement to deploy the MORL modules and elevator tubes, the shortening of the central cylinder, the reduction of its diameter to the same as the MORL, and the reduced requirement for pressure seals all tend to simplify the concept. This is reflected in a less demanding schedule and reduced costs. The total costs in 1965 dollars are $802.4 million compared to the initial OLF cost of $861 million, for a net saving of close to $60 million.

6.2 R & D Scientific Experiments. - One of the very desirable aspects of providing a permanent facility in orbit for supporting orbital launches, as opposed to temporary vehicles which are sent into orbit for only the duration of the orbital launch operations, is the availability of what will undoubtedly be a fairly large orbiting facility for scientific research and development work during the periods in which it is not engaged in orbital launch operations. It may also be desirable that the facility be so designed as to allow some R&D work even during orbital launch operations. The suggestion of these possibilities was the basis for analyzing the OLF's capability of supporting such activities and investigating what the requirements are to accommodate such work.

6.2.1 Approach. - Assessment of the OLF requirements for supporting orbital experimentation requires, first, some idea of what that experimentation might be. Obviously, the possibilities of experiments that might be desirable to accomplish on board the OLF are innumerable.

Orbital experiments which would be required in the development of the initial OLF and initial orbital launch operations capability were not considered as applicable in this study unless the same experimentation must be continued for advanced systems development. To further narrow the analysis to manageable proportions, eligible experiments from such other programs as AES, MORL, and OSSS, were reviewed and assigned priorities according to their applicability to the following categories (shown in order of the priority established for this analysis):

(1) Advanced orbital launch operations;

(2) Long-range space navigation;

(3) Long-range space communications and tracking;

(4) Improved structures and materials;

(5) Improved space repair techniques;

(6) Satellite retrieval, repair, and reorbiting;

(7) Space medicine

Tabulated requirements for each of the experiments--in terms of facility and personnel requirements, environmental considerations and logistics requirements--were then evaluated in conjunction with OLF design and operational limitations, and the priority in terms of each experiment to determine the most desirable and most applicable experimentation to be performed on board the OLF established.

6.2.2 Results. - Figure 6.2-1 summarizes the design and operational limitations of the recommended OLF concept with respect to those factors that may influence or dictate the type and number of experiments that could be accomplished on-board the OLF during non-OLO periods. The primary deficiencies for accommodating on-board experimentation are electrical power and station orientation. Additional provisions would have to be made in both areas.

Comparisons of the requirements of 97 experiments with the OLF design and operational limitations and considering the importance (priority) of the various experiments with respect to the enhancement of advanced OLO development, resulted in 68 experiments being found desirable for performing on the initial OLF. The 29 found not feasible were discounted primarily on their restrictive orbital requirements, which differed from those intended for the initial OLF.

Of the 68 experiments selected, 22 are experiments formulated as part of this study primarily to develop the capabilities of coordinated OLF/OSAV (Orbital Support Assembly Vehicle) operations that will be required in the advanced OLF operations in OLO.

FIGURE 6.2-1 OLF DESIGN AND OPERATIONAL LIMITATIONS

OLF DESIGN OR OPERATIONAL FACTORS	LIMITATIONS
Orientation	Randon orientation normally; fixed orientation with ± 0.5 degree attitude control on ± 0.01 degree/second rate only during docking operations, once every 30 days.
Orbit	535 km (289 n.mi.) altitude circular orbit; 28°-33° inclinations.
Life	5 years with presently unestimated number of orbital launches each lasting about 6 months.
Pressurization	MORL modules, elevator tubes and terminal normally pressurized to 48,261 newtons/meter^2 (7 psi) with 50-50 O_2 and N_2 hangar and experiment bays normally pressurized to 24,130 newtons/meter^2 (3.5 psi), but capable of being pumped up to 48,261 newtons/meter^2 (7 psi) or down to hard vacuum. (One at a time only).
Electrical Power	Isotope/Brayton cycle -- 2 units each rated at 5.5 kWe (7.0 kWe continuous overload). Bus power 2.65 kWe of 24-31V rectified D. C. and 4.08 kWe of 115/200V 3,400 cps AC. All required for OLF normal operation. Experimental power must be provided.
Experimental Volume	Experiment and hangar bays of 471.5 m^3 (16,650 ft^3) each. MORL sanctuaries (2) of 59.2 m^3 (2,102 ft^3) each.
Experimental Crew	Normal crew of 4 men completely occupied in OLF operation and maintenance. OLF capable of supporting 12 persons continuously and 18 people for 15-day period.

6.3 Definition of ORL Experiments. - A prime objective of advanced missions studies should be the identification of Earth-based and particularly orbital-research requirements for the particular mission being studied. This is necessary not only because of the long lead time required in planning and designing research facilities but also for program evaluations and justification when viewed from the standpoint of the overall space program. The objective of this part of the OLF study was to identify some of the orbital research necessary for the OLF development and to provide preliminary planning for accomplishing that research.

6.3.1 Approach. - The basic approach used in this experimentation study (Figure 6.3-1) was intended to determine what constituted a basic orbital launch capability; how much of that capability would be achieved within the current planning and studies of Gemini, Apollo, AES and MORL programs; what capability would remain to be developed; and how and when should this additional developmental experimentation be accomplished. Under the direction of NASA, an experiment investigation committee was organized with representatives from each of the associated contractors making up the committee. Comparisons were made of the operations and systems requirements anticipated for a typical orbital launch of a Mars/Venus Flyby vehicle with the capabilities that could be expected to be achieved within the development and orbital experiment programs currently considered for Gemini, Apollo, AES and MORL. Experiments or series of experiments were postulated to make up the deficiencies found between current orbital experiment planning and the requirements for an initial orbital-launch capability. Each experiment was then defined by the particular contractor (Boeing, LTV, or Lockheed) most closely associated with or dependent upon that experiment in their respective studies. The experiment definitions were detailed to the extent that reasonable estimates of experimental development and implementation requirements could be made. The experimentation requirements were then summarized for each study (OLF, SCALE, and

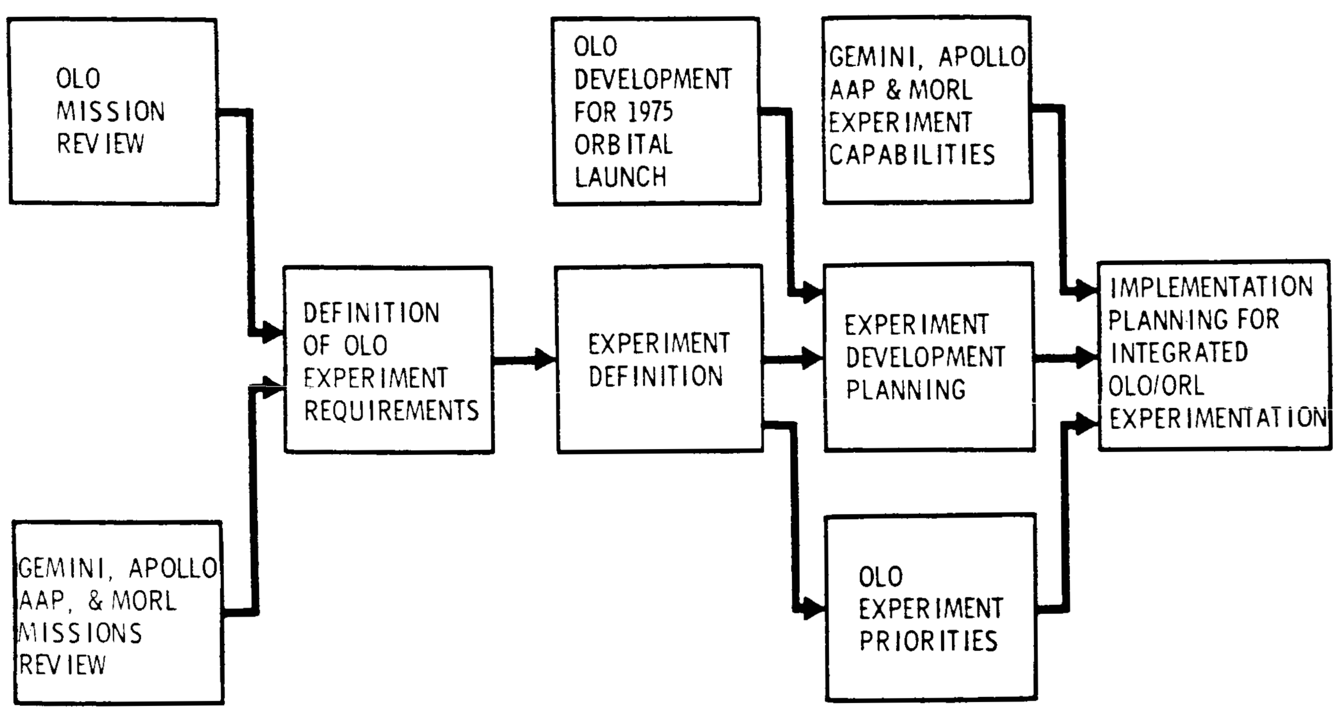


Figure 6.3-1

AOLO) and submitted to LTV for integration of all OLO orbital experimentation.

6.3.2 Results. - In the review of a typical orbital-launch operation, using the permanent-facility mode of support, eleven categories of operation requirements were established for comparison with the capabilities expected to be developed in the Gemini, Apollo, AES, and MORL programs. These categories included:

(1) Orbital transfer and rendezvous (OTR);

(2) Docking (D);

(3) Personnel transfer/artificial gravity (PT/AG);

(4) Personnel transfer/zero gravity (PT/ZG);

(5) Cargo transfer/artificial gravity (CT/AG);

(6) Cargo transfer/zero gravity (CT/ZG);

(7) Erection and assembly (EA);

(8) Maintenance and repair (MR);

(9) Fluid/propellant transfer and storage (F/PTS);

(10) Checkout (C/O);

(11) Launch (L).

For comparison of these categories of OLO requirements with corresponding aspects of the contemplated ORL programs, levels of capabilities development had to be assumed for the Gemini, Apollo, AES, and MORL programs. These detailed assumptions are itemized in Section 6.3.2.1, and particularly in Figures 6.3-2 and 6.3-3, of the detailed Technical Report. Those assumed levels of capability along with the vast listings of possible experiments that have been proposed for the ORL programs were reviewed with respect to the orbital-launch operational capability required in each of the designated categories. Of the 51 areas of experimental requirements identified, 20 were most applicable and, therefore, assigned to the OLF study for definition and development planning. Figure 6.3-2 summarizes the estimated mass, volume, power, duration, and manpower requirements, along with any specific orbit or flight requirements, for each of the 20 assigned experiments and one subexperiment. The total manpower estimate for that experimentation amounted to 2279 man hours. Note, that this represents only a first indication of what some of the orbital experimentation requirements for the OLF development may be. More detailed OLF preliminary design and operational studies will undoubtedly uncover more, some of which may be expansions or extensions of some of those defined in this study. Detailed descriptions of the 21 experiments are included in the detailed Technical Report.

The importance of each experiment with respect to the OLF development was defined through a ranking system established by the OLO experimentation committee. The four primary criteria established in the priority system takes into considera-

NO.	EXPERIMENT TITLE	ORBIT	MASS Kg - (lbm)
PT/AG-1	Intravehicular Transfer - Rotating Station (Personnel)	Any	126 (280)
PT/AG-2	Extravehicular Transfer - Rotating Station (Personnel)	350-550 km 28°-33° Incl.	305 (675)
CT/AG-1	Extravehicular Transfer - Rotating Station (Cargo)	350-550 km 28°-33° Incl.	416 (920)
CT/AG-2	Intravehicular Transfer - Rotating Station (Cargo)	Any	213 (470)
CT/ZG-1	Conveyor System - Zero Gravity	Any	207 (455)
CT/ZG-2	Separation System - Spacecraft Modules	Any	663 (1460)
EA-1	Vacuum Welding Techniques	Any	530 (1170)
EA-2	Extendable Umbilical Tower	Any	547 (1205)
EA-3	Extendable Structures Operations	Any	127 (280)
EA-4	Internal Structural Assembly Procedures	Any	417 (920)
EA-5	Removal, Transfer & Installation of Passive Structure	Any	435 (960)
EA-7	OLF Stabilization with Scaled OLO Hardware	Any	794 (1754)
EA-10	Space Vehicle Static Electricity Potential	350-550 km 28°-33° Incl.	122 (270)
MR-1	Structural Repair-Welding Techniques	Any	530 (1170)
MR-2	Structural Repair-Emergency Tech.	Any	454 (1000)
MR-3	Special Personnel Tools	Any	125 (275)
MR-4	Special Repair Shop Tools	Any	226 (500)
MR-4-1	Special Repair Shop Tools-Integrated Electronic Circuitry Repair Equip.	Any	45 (100)
MR-5	Leak Detection-Life Support Structure	Any	118 (260)
L-1	Thrust Motor-Jet Exhaust Effects	Any	323 (710)
L-2	Space Vehicle Explosion-Debris Hazard	350-550km 28°-33° Incl.	545 (1200)

2

VOLUME m^3 - (ft^3)	POWER (watts)	DURATION (days)	TIMES/ FLIGHT	MAN-HRS/ DAY	TOTAL MAN-HRS.
0.62 (21.9)	350	8	4	15.0-16.5	126
0.98 (34.7)	350	4	8	22.5	90
1.11 (39.2)	550	6	12	21.0	126
0.70 (24.6)	550	2	4	33.0	66
0.46 (16.3)	700	4	8	14.0	56
1.01 (35.6)	Undefined	Undefined	Undefined	Undefined	400
1.25 (43.8)	1500 Peak	6-12 Mos.	1	9.0	27
1.45 (51.3)	900 Peak	1 Yr.	20	10.0 1st 3 days	50
0.37 (13.1)	1000 Peak	2 mos.	60	5.0 initial 0.7 daily	52
0.59 (20.7)	1000 Peak	6	6	16.5	99
1.17 (41.4)	350	5	10	16.8	84
5.28 (187)	600	6	3	22.5	135
0.17 (6.0)	400 Peak	6-12 Mos.	Undefined	Undefined	200
1.24 (43.8)	1500 Peak	Undefined	Undefined	Undefined	100
0.62 (22.0)	1000 Peak	Undefined	Undefined	Undefined	200
0.39 (13.8)	700	Undefined	Undefined	Undefined	30
0.25 (8.7)	6000 Peak	7	12	12.6	88
6.34 (224)	60	10	10-15	7.0	70
0.40 (14.0)	350	Undefined	Undefined	Undefined	100
0.64 (22.6)	200	10	10	8.0	80
0.96 (34.0)	600	Undefined	Undefined	Undefined	100
					2279

Figure 6.3-2

Figure 6.3-3 EXPERIMENT RANKING

RANKING	EXPM'T NO.	EXPERIMENT TITLE
I	EA-10	Space Vehicle Static Electricity Potential
II	L-2	Space Vehicle Explosion - Debris Hazard
III	PT/AG-2	Extravehicular Transfer-Rotating Station (Personnel)
	MR-1	Structural Repair - Welding Techniques
	MR-2	Structural Repair - Emergency Techniques
	MR-5	Leak Detection - Life Support Structure
IV	CT/AG-1	Extravehicular Transfer-Rotating Station (Cargo)
	EA-3	Extendable Structures Operation
V	EA-7	OLF Stabilization with Scaled OLO Hardware
VI	EA-1	Vacuum Welding Techniques
VIII	PT/AG-1	Intravehicular Transfer-Rotating Station (Personnel)
	EA-2	Extendable Umbilical Tower
VIII	CT/ZG-2	Separation System - Spacecraft Modules
	EA-4	Internal Structural Assembly Procedures
	MR-4	Special Repair Shop Tools
IX	CT/ZG-1	Conveyor System - Zero Gravity
	MR-4-1	Special Repair Shop Tools - Integrated Electronics Circuitry Repair Equipment
X	CT/AG-2	Intravehicular Transfer - Rotating Station (Cargo)
XI	EA-5	Removal, Transfer & Installation of Passive Structure
	MR-3	Special Personnel Tools
XII	L-1	Thrust Motor _ Jet Exhaust Effects

tion man-related development research, new hardware development, systems operations research, and developmental research for formulating or proving OLO procedures. The ranking of the 21 experiments with respect to their importance in the OLF design and operations development is presented in Figure 6.3-3.

Experiment development estimates for purposes of development and implementation planning were classified as "simple", "normal", and "difficult", for which time estimates of 2.5, 3, and 3.5 years were assigned respectively. The development times and assumed dates of required data availability, as determined by the OLF RDT&E program, established experiment development go-ahead dates. Experimentation schedule estimated in comparison with NASA-prescribed Orbital Research Planning Schedules for Gemini, Apollo, AES and MORL are shown in Figure 6.3-4. All of the experiments required for the OLF development precedes the postulated availability of the MORL systems but coincides with the predicted availability of AES. The experimental requirements, as defined, can be accommodated in AES as currently conceived, although some extended experiments would have to be completed on successive AES flights.

The experiments identified in this study represent a reasonable cross section of orbital research requirements for OLF development beyond that currently being considered in the pre-OLF programs. No experiment integration was attempted in the OLF study.

CATEGORY & EXPERIMENT NUMBER	EXPERIMENT TITLE	1966 1	2	3
PT/AG-1	Intravehicular Transfer - Rotating Station (Personnel)			
PT/AG-2	Extravehicular Transfer - Rotating Station (Personnel)			
CT/AG-1	Extravehicular Transfer - Rotating Station (Cargo)			
CT/AG-2	Intravehicular Transfer - Rotating Station (Cargo)			
CT/ZG-1	Conveyor System - Zero Gravity			
CT/ZG-2	Separation System - Spacecraft Modules			
EA-1	Vacuum Welding Techniques			
EA-2	Extendable Umbilical Tower			o
EA-3	Extendable Structure Operations			o
EA-4	Internal Structural Assembly Procedures			
EA-5	Removal, Transfer & Installation of Passive Structure			o
EA-7	OLF Stabilization w/Scaled OLO Hardware			
EA-10	Space Vehicle Static Electricity Potential	o		
MR-1	Structural Repair - Welding Techniques			
MR-2	Structural Repair - Emergency Techniques			
MR-3	Special Personnel Tools			
MR-4	Special Repair Shop Tools			
MR-4-1	Special Repair Shop Tools - Integrated Circuitry			
MR-5	Leak Detection - Life Support Structure		o	
L-1	Thrust Motor - Jet Exhaust Effects			
L-2	Space Vehicle Explosion - Debris Hazard			

ORBITAL RESEARCH PLANNING SCHEDULE

	1	2	3
Gemini - Orbital Missions			
Apollo - Orbital Missions			
AES-ORL - Orbital Missions			
MORL - Orbital Missions			

LEGEND:

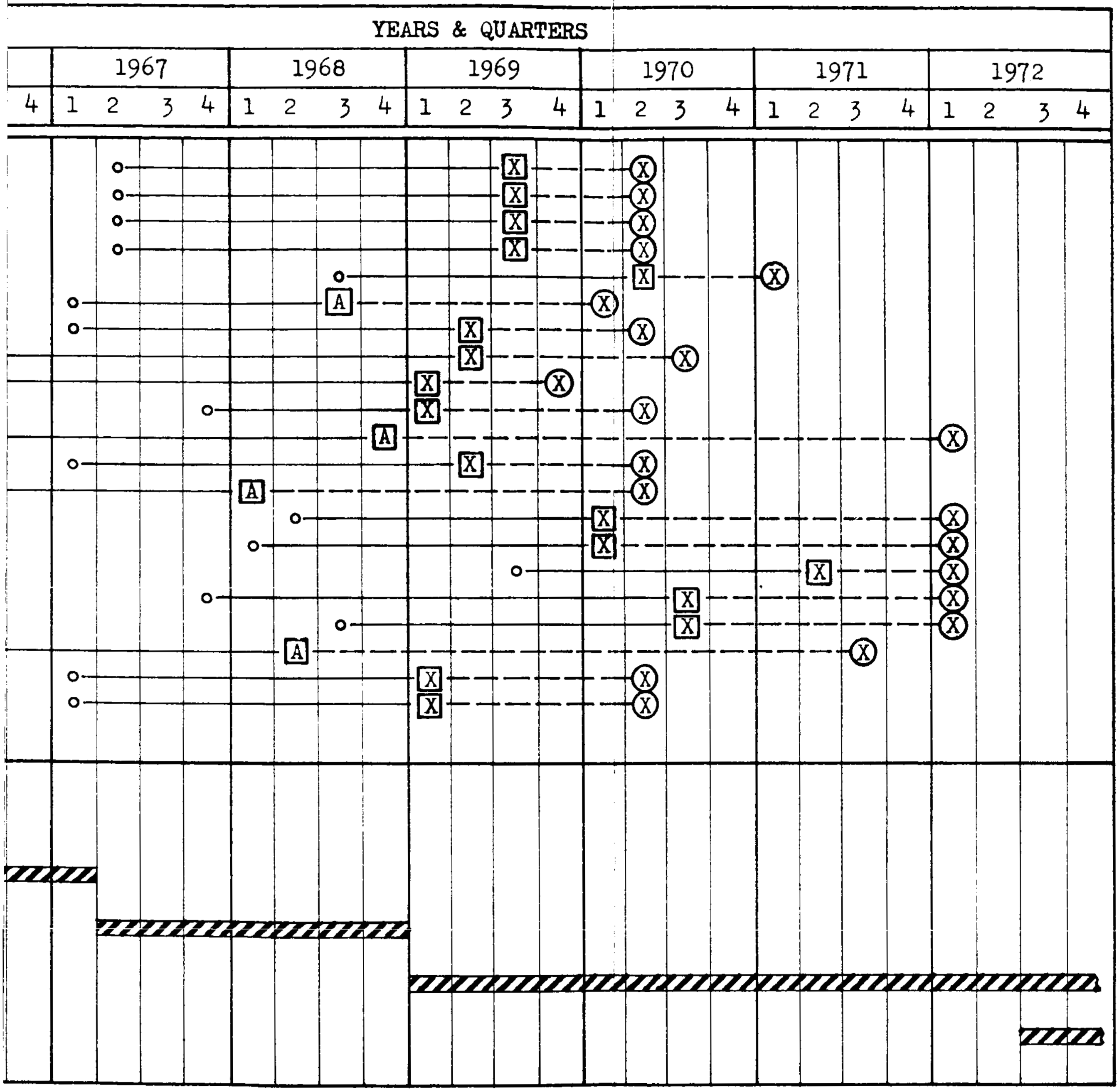
○ -Latest Date for data

□ -Desired date for data

o Development Go-ahead date based on desired da

A Apollo - Applicable System

X AES - Applicable System



e for data

Figure 6.3-4

7.0 OLF DEVELOPMENT PROGRAM

The objective of this part of the OLF study was to provide at least preliminary answers to the question of what is required to provide an operational system. A realistic comparison of various possible modes of performing orbital launch operations demands reasonable estimates of the research, design, test, and engineering (RDT&E) requirements for providing the systems and operational capabilities required by the modes to be compared. One of the primary systems of the permanent-facility mode of orbital launch operations is the OLF itself. A preliminary integrated RDT&E plan for the OLF was developed to provide this desired information. The plan determines and describes the design, development, research, test activities, and resources necessary to provide an operational, intial OLF for support of a 1975 Mars/Venus flyby mission. A cursory study was also performed to provide a very brief RDT&E plan for an OLF to support the manned Mars-landing and Lunar-Ferry missions.

7.1 Initial OLF RDT&E Plan. - The initial OLF RDT&E plan includes a schedule plan, design and development plan, research plan, manufacturing plan, system and qualification test plan, reliability plan, logistics plan, facilities and support-equipment plan, management plan, and a funding plan. From those the following conclusions are drawn;

(1) The RDT&E program for the initial OLF will require approximately 4 years from hardware design go-ahead to launch.

(2) A prime characteristic of the recommended initial OLF concept, use of MORL and Apollo building blocks, will minimize hardware research requirements.

(3) The total development program cost is estimated at $861 million.

(4) Detailed experiment definition and formulation of an ORL experimentation implementation plan is required to commence in the beginning of 1966.

(5) Existing facilities generally can be utilized; some expansion of simulator facilities will be required.

(6) Extended orbital checkout acceptance testing of the OLF and OLO prior to mission application is recommended.

(7) Many existing Saturn fabrication and assembly tools can be used in OLF manufacturing.

Each of the subplans are summarized in the following paragraphs.

7.1.1 Schedule Plan. - The operational capability date for this study is 1975 for the initial OLF. The RDT&E schedule to meet this target date is shown in Figure 7.1-1. This schedule shows a development requirement of approximately 4 years from hardware go-ahead to OLF launch to orbit, and a requirement of approximately 9 years from subsequent engineering studies to OLO planetary mission application. This is a normal RDT&E program with emphasis on orderly development and systematic solution of technical problem areas.

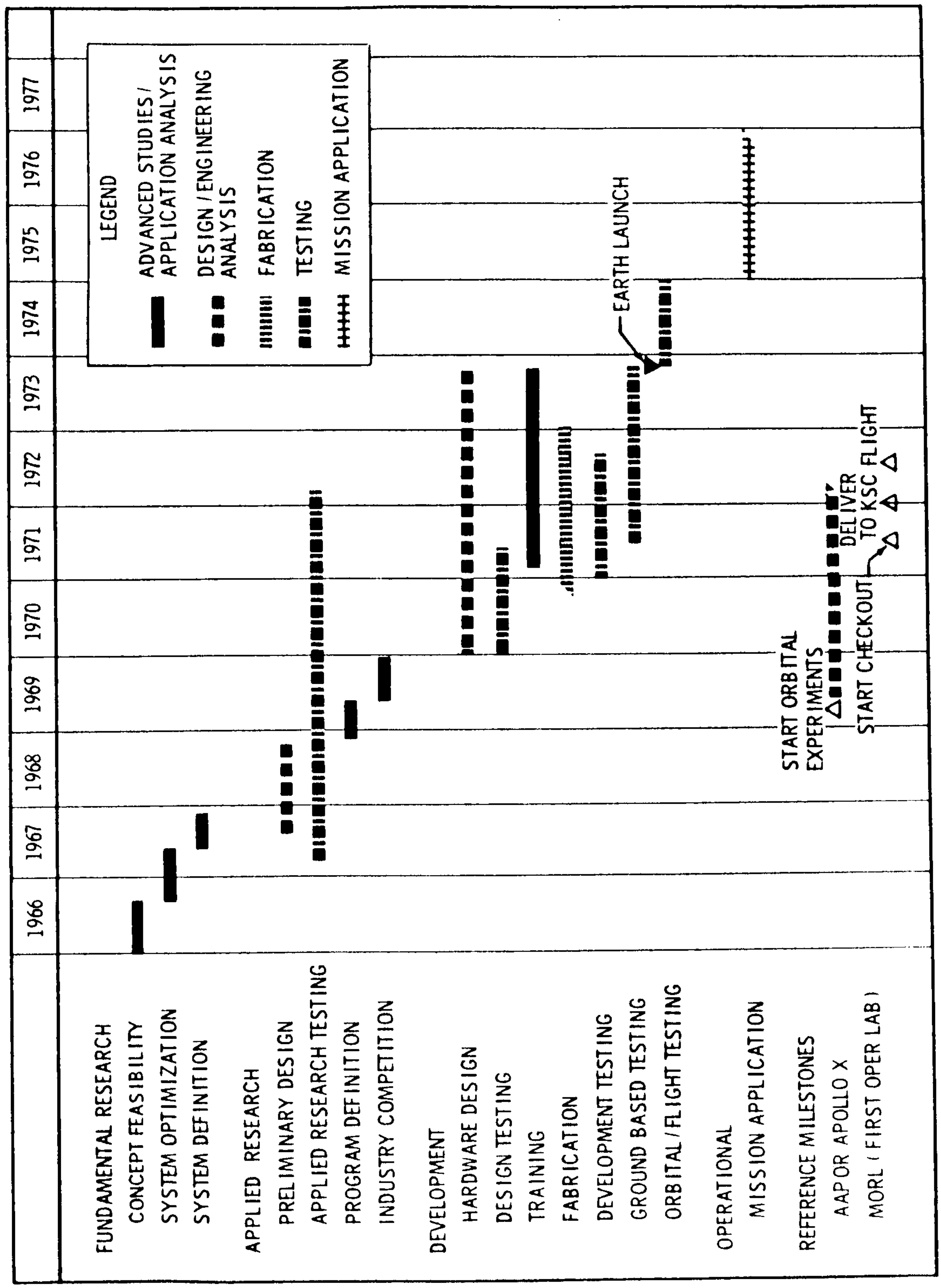

1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
LEGEND
ADVANCED STUDIES / APPLICATION ANALYSIS
DESIGN / ENGINEERING ANALYSIS
FABRICATION
TESTING
MISSION APPLICATION
FUNDAMENTAL RESEARCH
CONCEPT FEASIBILITY
SYSTEM OPTIMIZATION
SYSTEM DEFINITION
APPLIED RESEARCH
PRELIMINARY DESIGN
APPLIED RESEARCH TESTING
PROGRAM DEFINITION
INDUSTRY COMPETITION
DEVELOPMENT
HARDWARE DESIGN
DESIGN TESTING
TRAINING
FABRICATION
DEVELOPMENT TESTING
GROUND BASED TESTING
ORBITAL / FLIGHT TESTING
OPERATIONAL
MISSION APPLICATION
REFERENCE MILESTONES
AAP OR APOLLO X
MORL (FIRST OPER LAB)
EARTH LAUNCH
START ORBITAL EXPERIMENTS
START CHECKOUT
DELIVER TO KSC
FLIGHT

Figure 7.1-1

Subsequent schedule study efforts should examine the feasibility of increasing the quantity of launch umbilical towers at KSC to reduce flow time for staging orbital launch operation and identify in more detail the ORL experiments and the orbital acceptance testing required.

7.1.2 Design and Development Plan. - The design phase of the OLF evolves the definition of specifications and fabrication drawings for the facility, ground-support equipment and operational requirements. The objective of the development phase will be to prove that the design does in fact comply with the requirements and specification. The two activities of design and development are intimately related and one phase follows the other in an iterative progression until an acceptable operational system evolves.

Beginning with the fundamental research phase of the plan operational analyses, trade studies, mission analyses, and concept simulation tests are utilized to first provide some confidence in the basic feasibility of the concept, then to optimize the systems and to provide the basic data required for the conceptual design of the systems, and finally to initiate investigation of basic technological problems.

The applied research phase of the plan iteratively accomplishes the preliminary system design and the resolution of technological problems through applied ground and orbital research testing. On the basis of the preliminary design, systems specifications, supporting plans, funding estimates, and implementation plans are derived as part of the program definition phase.

Hardware design begins the development phase as soon as hardware go-ahead authorization is given. Initiation of the design release for the first vehicle, a structural test vehicle, is estimated at approximately 8 months after go-ahead, with a critical design review approximately 12 months after go-ahead. Design and developmental testing then follow for verification of the hardware design. The development phase includes all on-board systems development, testing, and qualifications from single components to the integrated OLF operational qualification tests.

7.1.3 Research Program. - The use of MORL modules in the initial OLF concept, with only minor variations in the structure and retention of the on-board systems concepts, provides some assurance that when the space program has progressed to the stage of needing an OLF, the selected systems, materials, techniques, etc., proposed for the initial OLF will be within the required state-of-the-art. However, some areas as identified in Section 6.3, "Definition of ORL Experiments," will require added research. The research requirements established within this study represent only the needs apparent at this level of study. More research requirements will undoubtedly become evident in future detailed studies.

The development program for the orbital experimentation includes:

(1) Definition of experiments and establishment of integrated experiment plan;

(2) Equipment design, development, test integration, and checkout;

(3) Procedure synthesis, integration, and checkout;

(4) Crew training;

(5) Final checkout of equipment, procedures, and crew;

(6) KSC checkout;

(7) Orbital-based testing and data analysis.

A "normal" experiment development schedule is presented in Figure 7.1-2. Comparatively simple and difficult experiment overall schedules are shown at the bottom. These schedule times are used as the basis for the implementation planning in Section 6.3

7.1.4 Manufacturing Plan. - The objective of the preliminary OLF manufacturing plan was to define preliminary tooling concepts, fabrication and assembly flow, facilities and equipment requirements, and manufacturing or quality control developments, and provide a basis for costing. The preliminary manufacturing plan also provides a basis for future study phases in the OLF development sequence. The plan provides for the use of existing tooling, facilities, processing techniques, and manpower skills to the maximum extent practical. Basic to the preliminary

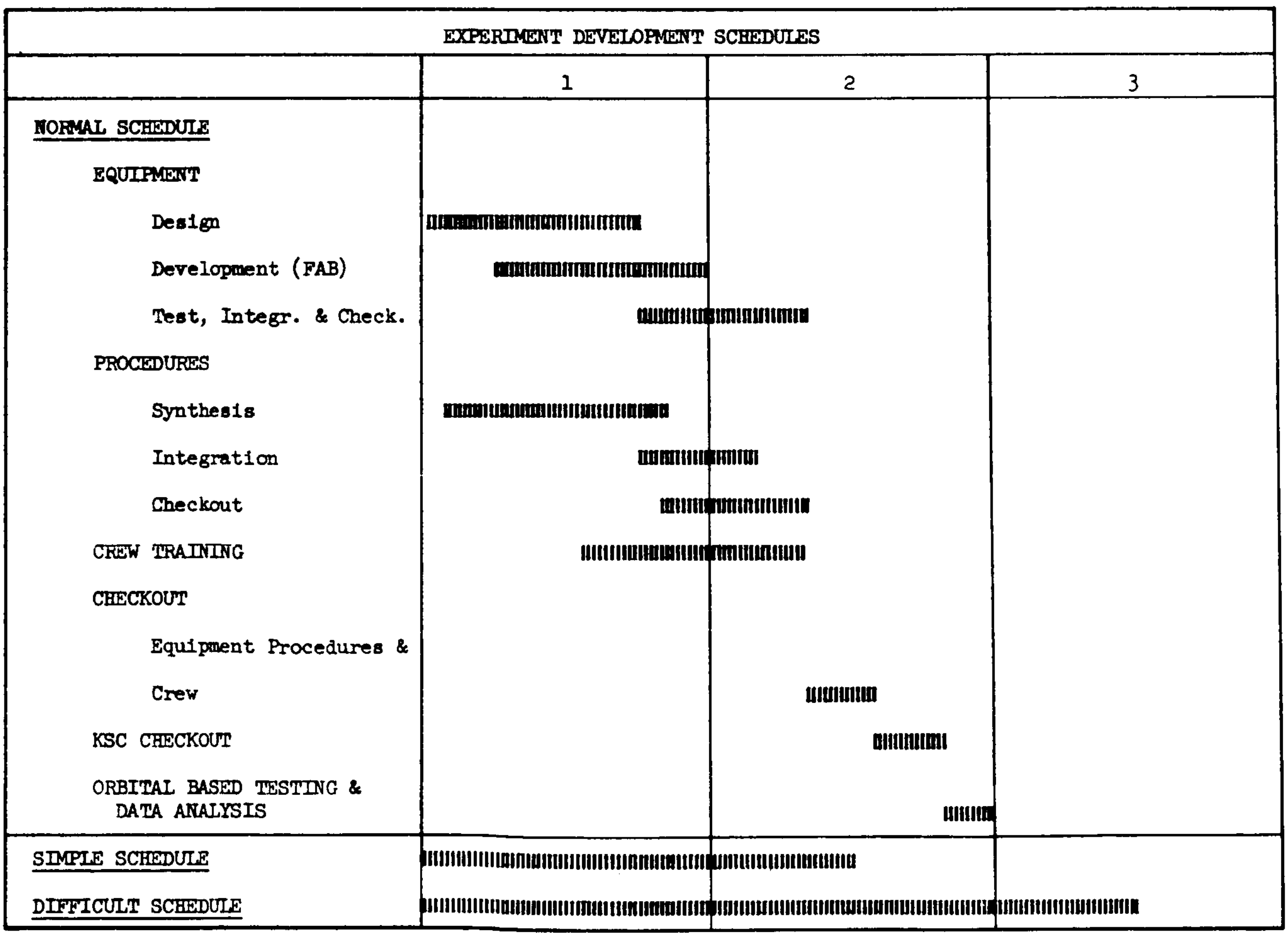


Figure 7.1-2

plan defined here is the use of a large existing manufacturing facility and major tooling, such as for Saturn S-IC or S-II, as explained in Sections 7.1.4.2 and 7.1.4.3 of the detailed Technical Report.

Equivalent OLF structural units required are a flight unit, a backup flight unit, a proof-test unit, a combination structural test and dynamic test unit, and portions equivalent to one unit for system and subsystem structural testing. It is assumed that the limited number of OLF spacecraft required will allow integrating the fabrication, assembly, and test of the OLF spacecraft with the Saturn S-IC (or S-II) program. Future study phases of the OLF spacecraft will require a detailed analysis of this aspect, including the influence of possible Saturn S-IC reusable launch configurations.

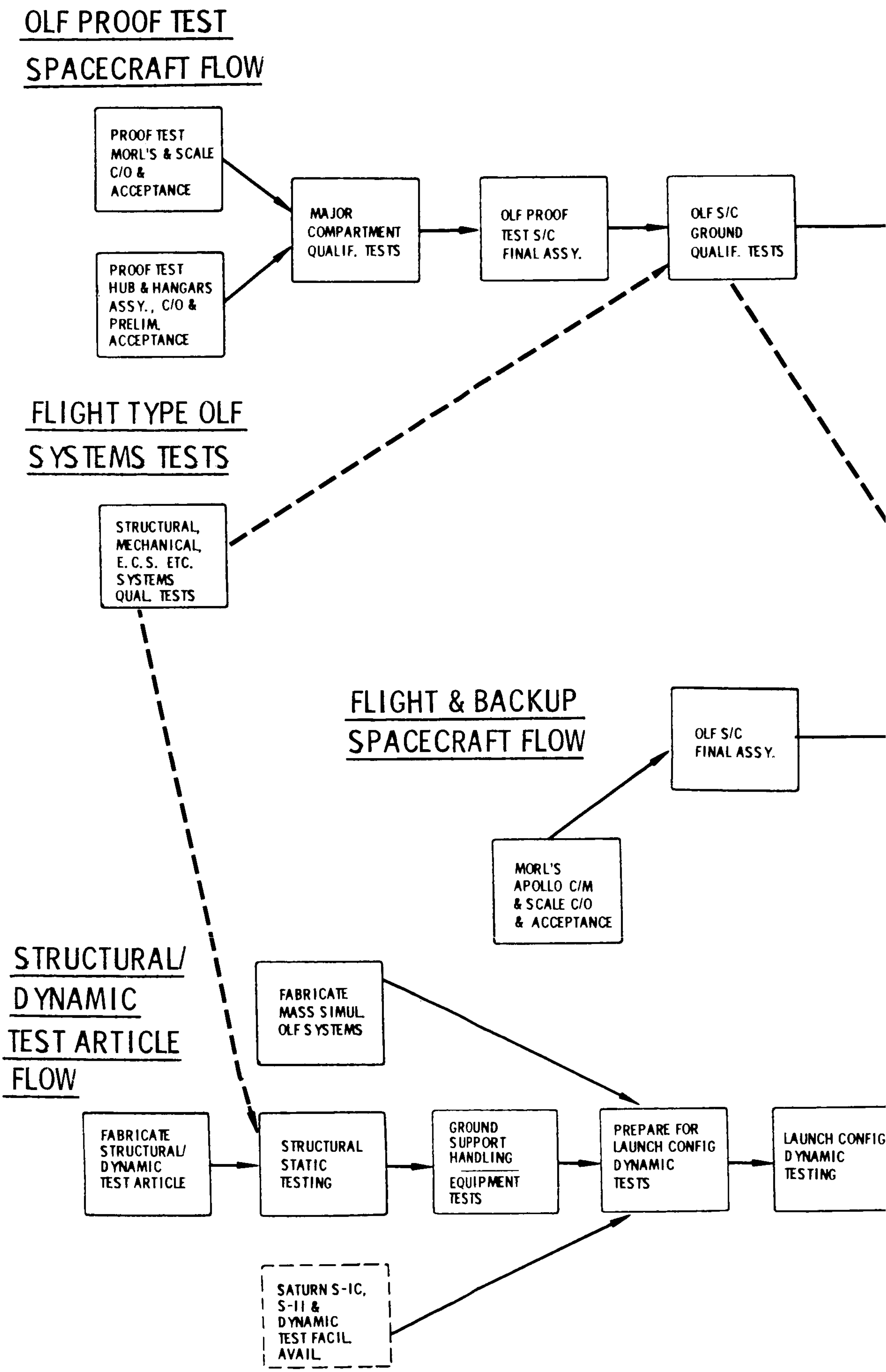
Although some consideration was given to make-or-buy plans in this study, this will be the subject for considerable study in future study phases.

A general plan for the OLF assembly, test, and shipping was formulated in this study, based in part on the S-IC stage manufacturing plan of Boeing Document D5-12561. That plan is itemized in the detailed Technical Report in Section 7.1.4.3.

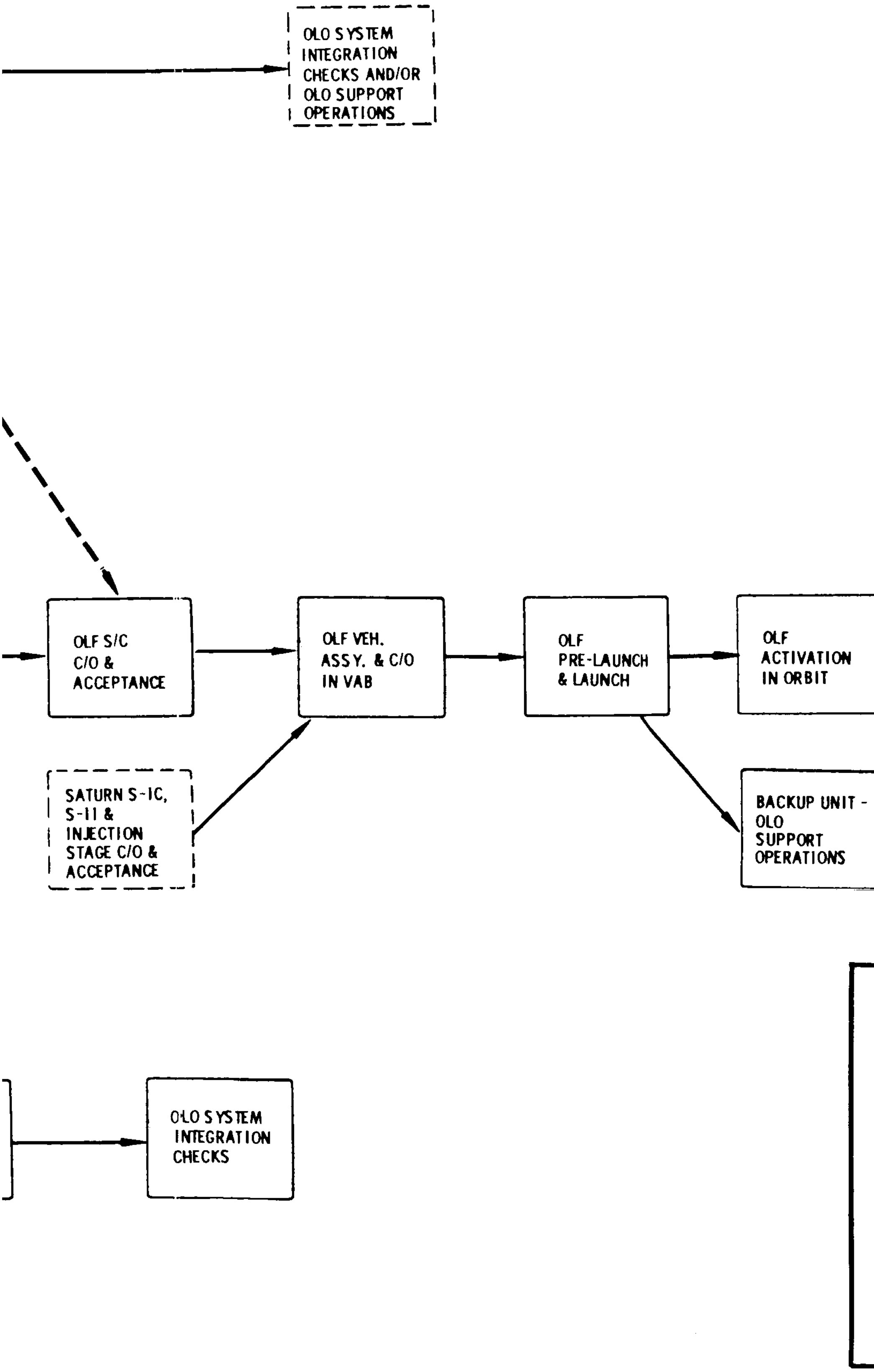
7.1.5 Systems and Qualification Test Plan. - The OLF spacecraft test plan is portrayed on the preliminary OLF test plan flow, (Figure 7.1-3) and the preliminary test plan schedule (Figure 7.1-4). These preliminary plans and schedules are to a level of detail consistent with the configuration definition and form a realistic baseline for present OLO and NASA plans.

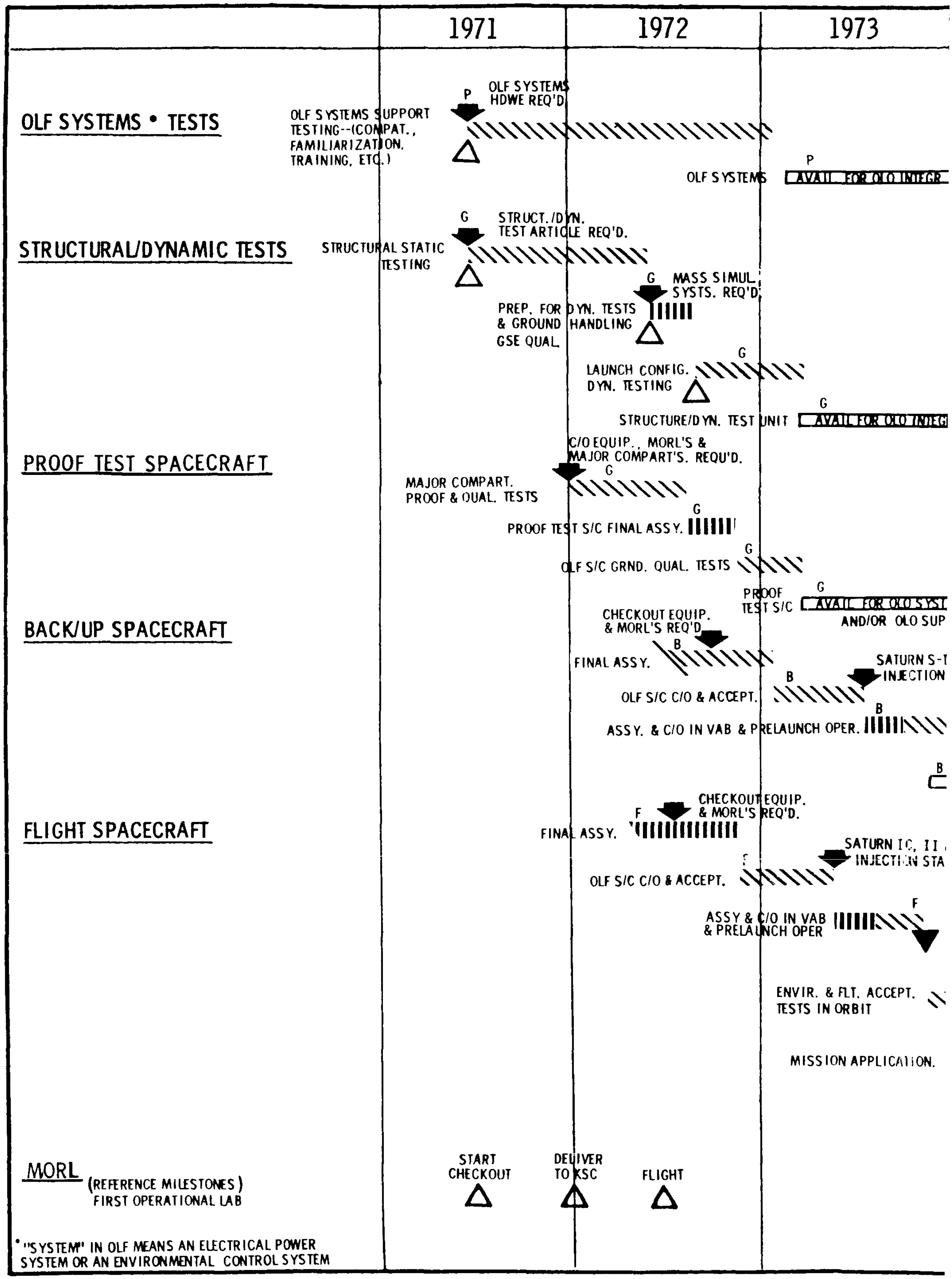
In brief the test plan approach assumed that since MORL and Apollo will be operational prior to the OLF, the extensive use of their hardware in the OLF will provide space-qualified hardware without additional major orbital test programs. Also, it assumes that final acceptance of the OLF spacecraft will be conducted in orbit on the operational spacecraft prior to actual orbital operations. This means that the OLF will be launched into orbit 530 days prior to commencing the flyby mission to allow acceptance testing on the OLF and the OLO system elements. The acceptance testing of the OLF will take 60 days, followed by OLO integrated systems tests that will last 330 days. During the integrated testing a nonmission OLV and a tanker will be orbited and docked. This testing will culminate with an orbital launch that simulates planetary mission, places the OLV in an elliptical Earth orbit, and allows use of the OLV reentry vehicle by the crew. Subsequent to the successful completion of this launch, the regular operations will commence with the orbiting of the mission OLV 140 days prior to OLO. Prior to the launch of the OLF, an extensive proof-testing program will be conducted. Five major compartmental areas (two MORLs, a hub, and two bays) will be assembled and tests conducted on a proof-test vehicle to verify static and dynamic loadings, operation of mechanism and the development of safety, and operating and maintenance procedures. This will be followed by ambient ground testing of the complete vehicle to include verification of electrical-power-load profile, heat-load profile, operational procedures, etc.

Four major spacecrafts are required for development and deployment. The four spacecrafts provide a unit for structural and dynamic testing, a proof test unit, a flight unit, and a flight backup unit.


OLF PROOF TEST SPACECRAFT FLOW
PROOF TEST MORL'S & SCALE C/O & ACCEPTANCE
PROOF TEST HUB & HANGARS ASSY., C/O & PRELIM. ACCEPTANCE
MAJOR COMPARTMENT QUALIF. TESTS
OLF PROOF TEST S/C FINAL ASSY.
OLF S/C GROUND QUALIF. TESTS
FLIGHT TYPE OLF SYSTEMS TESTS
STRUCTURAL, MECHANICAL, E.C.S. ETC. SYSTEMS QUAL. TESTS
FLIGHT & BACKUP SPACECRAFT FLOW
OLF S/C FINAL ASSY.
MORL'S APOLLO C/M & SCALE C/O & ACCEPTANCE
STRUCTURAL/ DYNAMIC TEST ARTICLE FLOW
FABRICATE MASS SIMUL. OLF SYSTEMS
FABRICATE STRUCTURAL/ DYNAMIC TEST ARTICLE
STRUCTURAL STATIC TESTING
GROUND SUPPORT HANDLING EQUIPMENT TESTS
PREPARE FOR LAUNCH CONFIG DYNAMIC TESTS
LAUNCH CONFIG DYNAMIC TESTING
SATURN S-IC, S-II & DYNAMIC TEST FACIL. AVAIL.

2


OLO SYSTEM INTEGRATION CHECKS AND/OR OLO SUPPORT OPERATIONS
OLF S/C C/O & ACCEPTANCE
OLF VEH. ASSY. & C/O IN VAB
OLF PRE-LAUNCH & LAUNCH
OLF ACTIVATION IN ORBIT
SATURN S-IC, S-II & INJECTION STAGE C/O & ACCEPTANCE
BACKUP UNIT - OLO SUPPORT OPERATIONS
OLO SYSTEM INTEGRATION CHECKS


1971
1972
1973
OLF SYSTEMS * TESTS
OLF SYSTEMS HDWE REQ'D
OLF SYSTEMS SUPPORT TESTING--(COMPAT., FAMILIARIZATION, TRAINING, ETC.)
OLF SYSTEMS
AVAIL FOR OLO INTEGR
STRUCTURAL/DYNAMIC TESTS
STRUCT./DYN. TEST ARTICLE REQ'D.
STRUCTURAL STATIC TESTING
MASS SIMUL. SYSTS. REQ'D
PREP. FOR DYN. TESTS & GROUND HANDLING GSE QUAL.
LAUNCH CONFIG. DYN. TESTING
STRUCTURE/DYN. TEST UNIT
AVAIL FOR OLO INTEG
PROOF TEST SPACECRAFT
C/O EQUIP., MORL'S & MAJOR COMPART'S. REQU'D.
MAJOR COMPART. PROOF & QUAL. TESTS
PROOF TEST S/C FINAL ASSY.
OLF S/C GRND. QUAL. TESTS
PROOF TEST S/C
AVAIL FOR OLO SYST AND/OR OLO SUP
BACK/UP SPACECRAFT
CHECKOUT EQUIP. & MORL'S REQ'D
FINAL ASSY.
SATURN S-I INJECTION
OLF S/C C/O & ACCEPT.
ASSY. & C/O IN VAB & PRELAUNCH OPER.
FLIGHT SPACECRAFT
CHECKOUT EQUIP. & MORL'S REQ'D.
FINAL ASSY.
SATURN IC, II INJECTION STA
OLF S/C C/O & ACCEPT.
ASSY & C/O IN VAB & PRELAUNCH OPER
ENVIR. & FLT. ACCEPT. TESTS IN ORBIT
MISSION APPLICATION.
MORL (REFERENCE MILESTONES) FIRST OPERATIONAL LAB
START CHECKOUT
DELIVER TO KSC
FLIGHT
* "SYSTEM" IN OLF MEANS AN ELECTRICAL POWER SYSTEM OR AN ENVIRONMENTAL CONTROL SYSTEM

2

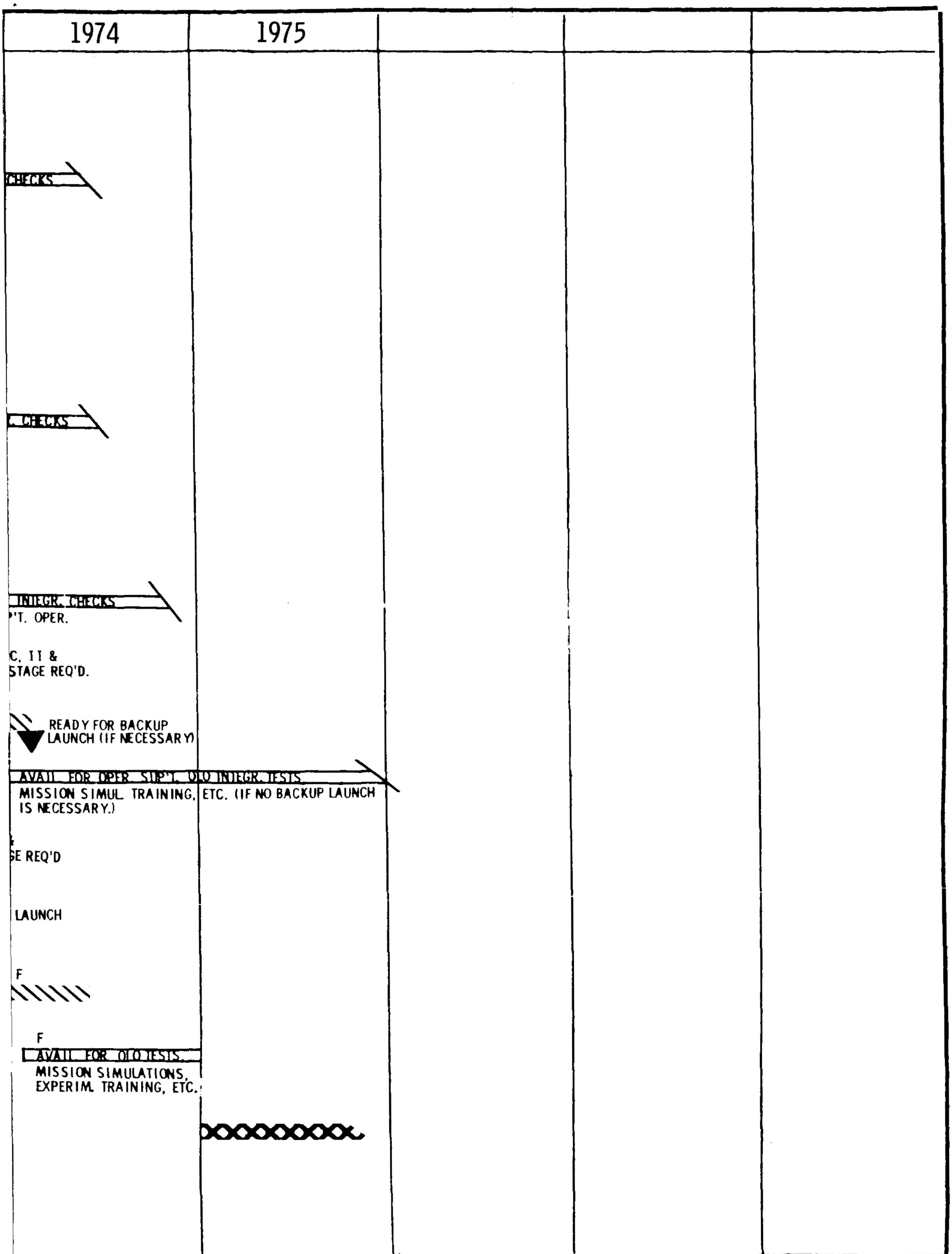

1974
1975
CHECKS
CHECKS
INTEGR. CHECKS
OPER.
STAGE REQ'D.
READY FOR BACKUP LAUNCH (IF NECESSARY)
AVAIL. FOR OPER. SUP'T. OLO INTEGR. TESTS
MISSION SIMUL. TRAINING, ETC. (IF NO BACKUP LAUNCH IS NECESSARY.)
REQ'D
LAUNCH
F
F
AVAIL. FOR OLO TESTS
MISSION SIMULATIONS, EXPERIM. TRAINING, ETC.

Figure 7.1-4

7.1.6 Reliability Plan. - The OLF reliability and safety program plan is a planning and control tool to assist the implementation and management of the program to ensure that the OLF will be developed to perform its required function within the performance requirements profile. The plan extends from the concept feasibility phase through the mission application phase of the RDT&E process. The purpose of this plan is to identify the reliability and safety tasks to be conducted to ensure a design capable of performing its planned function with a realistic probability of success. This plan is based on the recently developed MOLAB reliability and safety plan (See Boeing Document D2-83301-3) and an in-house special study resulting in a guide for reliability program plan development (Boeing Document D2-20459-1).

The discussion covering the reliability activities from the concept feasibility phase through the system definition phase is unique in the OLF plan. To avoid sacrificing clarity for brevity, the reliability plan, as such, is not summarized herein beyond the very brief explanation of its purpose and basis presented above. Reference is made to the complete discussion in Section 7.1.6 of the detailed Technical Report.

7.1.7 Logistics Plan. - Logistics encompasses the equipment, material and services required to operate and maintain the OLF during the life of the program. Experience has shown that timely and adequate logistics support is essential to successful operation of a system and the completion of its objectives. To ensure consideration of all support requirements, a systems engineering approach was used to determine the logistic elements essential to support of the OLF. This approach was used to determine the operation OLF logistic requirements, as presented in Section 4.5.

Operational and maintenance concepts for the ground-based functions of the OLF, which are compatible with existing NASA capabilities, have to be developed. Each major event in the ground-based cycle of OLF events should be analyzed to determine logistic requirements for operation and maintenance of the OLF during assembly, test, checkout, prelaunch, and launch.

A program of training and training support, both ground-and orbital-based, should be developed and conducted to ensure the success of the OLF mission. Training should be provided to OLF flight crew personnel, NASA personnel, OLF contractor personnel, and other agencies or contractors directly involved in the OLF program. The OLF training requirements should be coordinated with NASA and other orbital launch operations contractors to ensure proper integration and compatibility with the total training program. Most of the training will probably be accomplished at existing NASA facilities with assistance or participation of OLF program contractors. The types of crew training required are: (1) systems and subsystems training, (2) component training, (3) maintenance training, (4) duty position training, (5) personal maintenance training, (6) flight simulator training, (7) emergency procedures training, (8) navigation and tracking, (9) physiological, (10) data management, (11) communications, (12) record keeping, (13) personnel, and (14) OSE.

System maintainability will be ensured through a program that includes the establishment of maintainability criteria and goals and the performance of maintainability evaluations of the appropriate stages of system design, OLF assembly, test, checkout, launch, and operational deployment in space.

Spares support includes all repair parts needed to adequately maintain and keep in operation the OLF systems and its associated ground equipment. Repair parts will range from major assemblies to the bits and pieces necessary to support the OLF during all phases of assembly, testing, and checkout in preparation for launch. Spares required during the in-orbit operational phase of the program are covered in Section 4.4 above.

Technical data will be required for ground support of the OLF and flight crew. Data required for ground support of the OLF and its GSE includes detailed system and subsystem descriptions; operating instructions; test and checkout instructions; transportation and handling instructions; and maintenance data, which should include servicing, adjustment, calibration, fault isolation and repair instructions.

The majority of this data will become available from engineering design and test procedures developed to accomplish the test program. The requirements for technical data will be reviewed against existing or proposed engineering documentation to determine what is suitable for field or test site use. Existing technical data for off-the-shelf and GFE will be used as much as possible.

7.1.8 Facilities and Support-Equipment Plan. - Facility and support-equipment requirements are evaluated and it was determined that the manufacturing capability required for the OLF would be available either from NASA or private industry and that the facilities to provide Apollo or MORL hardware would also be available. Full and partial-mission simulators will be provisioned at Houston and housed in a semi-clean enclosed high bay area, to which will be a low bay area for consoles, computer racks, etc. This facility will be a modification of the existing MORL mission-simulation facility. A new transporter or dolly will have to be provisioned for handling the OLF and for transportation between the various complexes. Subsequent studies are required to define the ground-support equipment. A ground network system using a unified "S" band communication system for a once-per-orbit transmission will require such typical sites as Corpus Christi, Antofagasta, and Quito. At present only Corpus Christi is equipped to support the OLF; the other stations would have to be upgraded.

7.1.9 Management Plan. - Because achievement of target performance and schedules within cost estimates is the primary management task, program management is concerned with two major segments -- OLF-OLO interfaces and OLF proper. Close coordination will be required with NASA and all the major contractors participating in orbital launch operations. The major coordination activities for OLF will be with the checkout and monitoring system and the OLO systems integration contractors. Coordination to a lesser extent will be conducted with the orbiting launch vehicle, orbital tanker, logistics vehicle, and booster contractors.

In accomplishing the OLF proper tasks, coordination for integration and interface planning and control will be established and maintained with NASA, the MORL contractor, the MORL system subcontractors, the Apollo contractor, and other government operating agencies concerned with the OLF proper programs.

Through all the phases of the initial OLF RDT&E, management, planning will be concerned with establishment and maintenance of task definition and schedules and with the definition and documentation of program controls, including technical, cost, schedule, and configuration control.

7.1.10 Funding Plan. The objective of the OLF costing was to develop a program cost of sufficient quality and validity for use in establishing a time-phased funding plan that allowed for successful accomplishment of the initial OLF.

Because the OLF program consists of Apollo and MORL building blocks and includes two modified MORLs, a center section including the hub, docking ports, and a six-man Apollo, there is a significant reduction of cost in the RDT&E phase for the OLF systems.

For cost planning purposes, the initial OLF RDT&E effort is defined as that portion of time from concept feasibility through the first 2 months of orbital OLF checkout and acceptance testing. This time period cutoff coincides with the start of the OLO in orbit checkout and acceptance testing prior to mission application.

The total program cost is $861 million for the OLF and includes the costs of design development, test, and fabrication of the orbital launch facility. The cost estimate summarized in Figure 7.1-5 follows the general format set forth in Project OLO Technical Information Release and is in terms of 1965 dollars. A funding plan phased to match the preliminary program scheduling is shown in Figure 7.1-6. The effect of projected annual escalation of costs is also shown.

7.2 Advanced OLF RDT&E Plan. - A preliminary advanced OLF RDT&E and cost plan was developed for the advanced OLF in support of a manned Mars landing mission. A similar preliminary cost plan was developed for lunar ferry operations. These plans were developed, based on the NASA point-of-departure plan, to support the Mars opportunity in the first half of 1983 and the start of lunar ferry operations in the first quarter of 1980. Both of these plans assume the initial OLF program is in being or has been conducted. These programs are costed independently of each other but both are dependent on an initial OLF technology.

7.2.1 RDT&E Plan - Mars Landing Mission - The Mars landing mission RDT&E schedule for this advanced application (Figure 7.2-1) shows a development flow time of approximately 30 months from hardware fabrication go-ahead to advanced OLF launch for orbital checkout and acceptance testing, and 42 months to the start of mission application.

The costs for a manned Mars-landing mission advanced OLF have been calculated on a weights variance analysis from the baseline initial OLF, and by estimating the sustaining engineering and test engineering level of effort required. The costs are predicted on an initial OLF having been accomplished and cover the time period until orbital checkout and acceptance testing. The costs developed, based on the same ground rules and criteria as Section 7.1.10 above, are:

	$ IN MILLIONS
System Procurement	120.0
Sustaining Engineering (Contractor)	18.0
OLF Personnel Training	10.0
Total	148.0

	Design & Dev.	Ground Test Hdwe.	Flight Test Hdwe.	Total Program Cost
Structure	110.0	62.7	44.2	216.9
Comm. & Data Mgmt.	8.3	15.2	15.9	39.4
Guidance & Nav.	5.0	6.8	6.2	18.0
Stab. & Control	10.8	13.4	12.2	36.4
Life Support	5.0	32.2	29.8	67.0
Env. Control	6.0	20.5	19.2	45.7
Ele. Power	38.4	23.9	103.4	165.7
Spares	-0-	14.8	15.6	30.4
OLO Tech.	24.9			24.9
Sys. Engr.	15.0			15.0
Tooling & STE	17.5			17.5
Grd. Test Ops.	20.0			20.0
Flt. Test Ops.	7.1			7.1
Sys. Integ.	16.0			16.0
Training	10.0			10.0
Training Equip.	10.0			10.0
OLO Supt. Prog.	15.5			15.5
Sys. Mgmt.	84.0			84.0
Test Facilities	3.5			3.5
Pre-Launch Facilities	1.0			1.0
APOLLO	-0-	-0-	17.2	17.2
1965 $ Total	408.0	189.5	263.7	861.2
Escalated	525.1	243.8	339.4	1,108.3

Figure 7.1-5

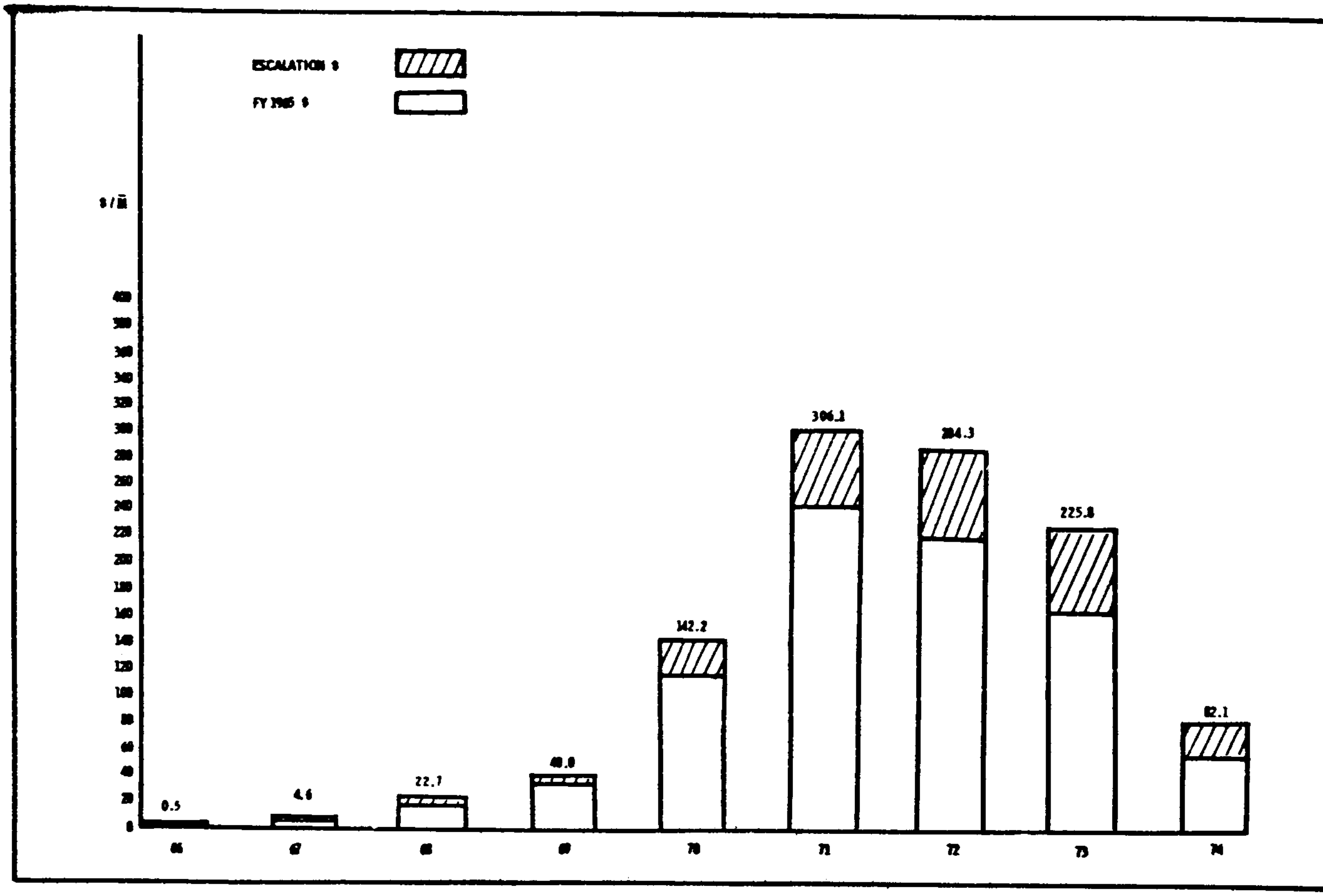


Figure 7.1-6

7.2.2 Cost Plan--Lunar Ferry Mission. - The lunar ferry mission advanced OLF will be of the same configuration and have the same RDT&E plan as the Mars-landing-mission advanced OLF, but in addition will allow cold flow tests of the propulsion system. The costs for this advanced mission support OLF are approximately the same, with the same ground rules applicable as the manned-Mars mission concept, and are tabulated below:

	$ IN MILLIONS
System Procurement	120.5
Sustaining Engineering (Contractor)	18.0
OLF Personnel Training	10.0
Total	148.5

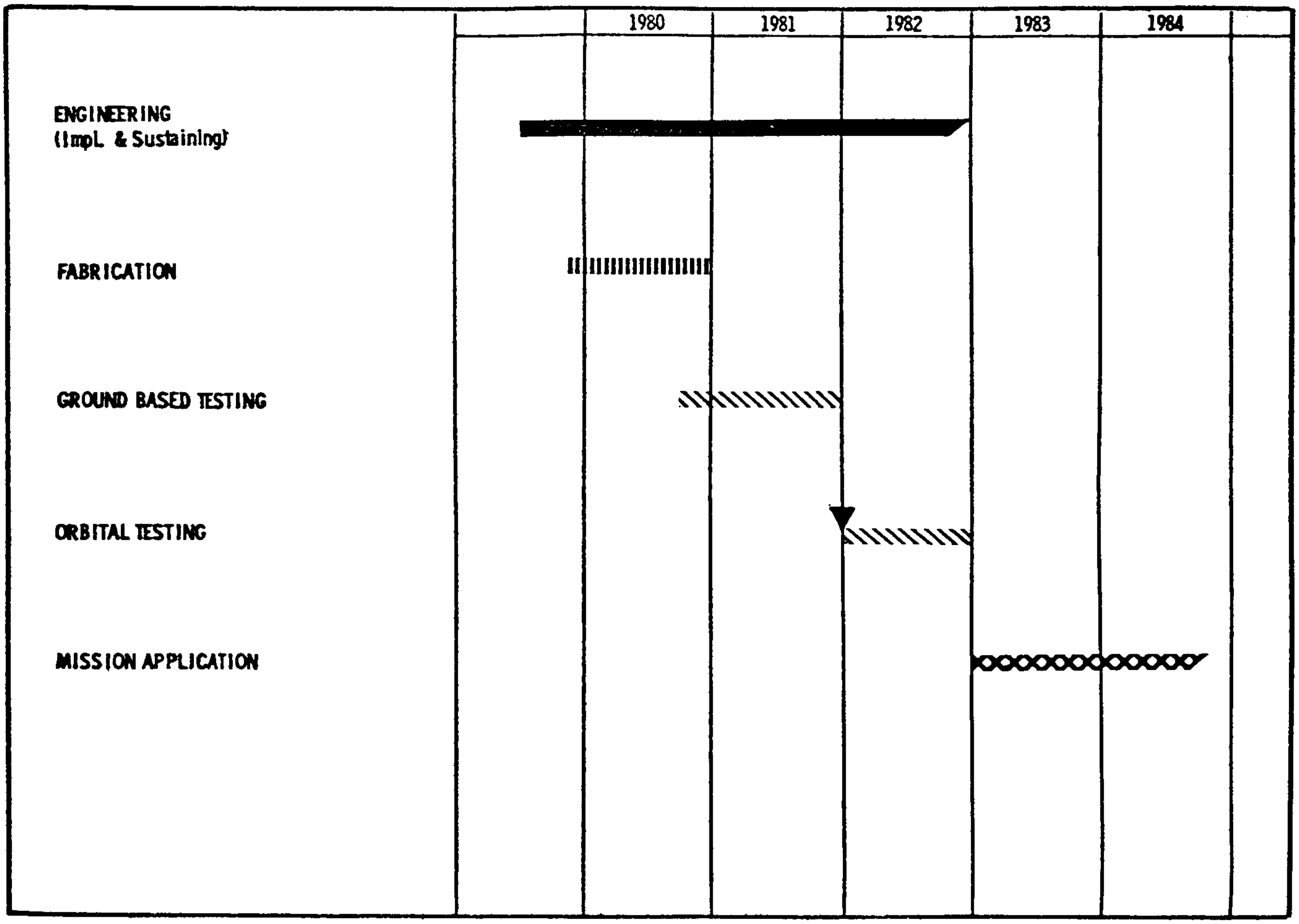

1980
1981
1982
1983
1984
ENGINEERING
(Impl. & Sustaining)
FABRICATION
GROUND BASED TESTING
ORBITAL TESTING
MISSION APPLICATION

Figure 7.2-1

8.0 CONCLUSIONS AND RECOMMENDATIONS

The OLF study as summarized in this document and discussed in detail in the Technical Report of Volume II A & B, fulfilled the objectives of this study and provided valuable insight into the problems that will be encountered in the research, development, testing, design, operation, and maintenance of an orbital launch facility. The conclusions reached in the OLF study reflect the feasibility of using a permanent-type OLF in an orbital launch operation. The different modes of interplanetary launches and orbital support modes, of which the OLF is one, are compared in the Ling-Temco-Vought AOLO study. Some of the more important conclusions derived from this study are:

(1) The recommended initial OLF design concept evolved from this study is considered to be a feasible facility design and a very effective instrument for the support of manned planetary missions. It appears to be well within the expected state-of-the-art for the time period of the early 1970's.

(2) The use of Apollo and MORL building blocks in the initial OLF concept significantly simplifies the RDT&E for the facility, which is estimated to require 4 years from hardware go-ahead to launch and will cost approximately 861 million dollars.

(3) The recommended initial OLF concept offers tremendous growth potential and is adaptable for support of such advanced missions as the manned Mars-landing and lunar-ferry missions with only minor modifications.

(4) Considerable advantage may be gained by integrating advanced missions support requirements into a composite OLF design as early as possible in the OLF development.

(5) The use of the OLF and R&D scientific experiments during the non-OLO period of orbital operation appears feasible and very appealing. Distinct effort should be directed at more detailed definition of the associated OLF support requirements and early integration of these requirements into the OLF development.

(6) An additional possibility of the OLF in the field of experiments in its use as a "mother" spacecraft for experiment modules. In this concept a multi-purpose mission module (MMM), or equivalent, is prepared on Earth for a particular family of experiments and is orbited and docked to the OLF, which then serves as a base of operations and quarters for the crew. The advantage of this would be that complete laboratories could be prepared on Earth, rather than modifying the OLF for each set of experiments while in orbit.

(7) Although the gravitational level analysis of this study was far from conclusive, indications are that unless physiological effects of extended weightlessness on man demand artificial gravity, a zero-gravity facility appears more desirable.

(8) In the investigation of the orbital experimentation that may be required in the development of the initial OLF, it was found that to achieve the 1975 target date for the initial OLF, all of the data available requirements fall

within the predicted AES period prior to MORL. However, all of the experimental requirements defined thus far are within the capabilities currently assumed for the AES.

(9) All of the ORL experiments defined in this study and scheduled in accordance with the initial OLF RDT&E plan require experiment development go-ahead within the 1966-1968 time period. Detailed ORL experiment definition and implementation planning should commence in 1966.

The following future activities are recommended based on the knowledge gained by the OLF study. While they are not all directly concerned specifically with OLF design and operation, they are concerned with OLO.

(1) To reduce crew radiation dosage or the radiation shielding requirements, a further evaluation should be made of the present 535 km orbital altitude to determine whether a lower altitude and/or different orbit inclination is feasible.

(2) Trade studies should be conducted to determine the optimum orbit altitude for the least propellant consumption, for the full 5 years of OLF life. (Drag coefficients vary from year to year.) Lowering the orbit altitude would increase orbit-keeping propellants slightly but could result in a substantial decrease in boost propellants, thus increasing logistic payloads. This would also be related to Item (1) above.

(3) During the study it was assumed that radiation was uniform. Point dosage must be studied in detail to determine the radiation shielding provided by the OLF structure and equipment.

(4) A reevaluation of the launch intervals constraints due to lack of launch umbilical towers (LUT) should be performed. The provisioning of additional LUTS would reduce the present 170-day OLO to a lesser period, shorten the time in space for men and equipment, and might result in an overall reduction in costs.

(5) A more detailed look should be taken at zero-g OLF concept-development, particularly if crew psychophysiological requirements allow prolonged zero-g operation.

(6) Future studies should be made of the integration of the initial OLF with advanced OLF design concepts to result in a multipurpose OLF. In this connection it will also be necessary to perform further studies to review the best supply mode for combined orbital operations. That is, hard-docking should be compared with remote, and possibly both modes retained as at present. Explosion and radiation hazards should be considered in these studies.

(7) The effects of orbital precession on orbital launch operations should be completely analyzed. This should include considerations of inclination and altitude on precession rate, precession rates on launch windows, and the related effect of orbital inclination on the launch opportunity.

(8) The R&D experiments study was limited to enumerating and describing those experiments that can be performed in the OLF. Further studies are required

to define and schedule those experiments that can be conducted concurrently with the initial orbital launch operation.

(9) Further detailed studies must be conducted on ORL experiments required in OLF and OLO development to ensure that they have been fully defined and integrated into the national space program.

(10) A ground-versus-orbit-testing philosophy must be developed in order to ensure a correct balance of testing.

(11) The effect of the OLF configuration on the Earth launch vehicle must be analyzed in detail because the S-II stage of the Saturn V is structurally marginal in this application. Perhaps environmental launch restrictions could be considered in lieu of design changes.

(12) Although numerous other study areas were revealed wherein more detailed or extended investigation is required, most of these areas will probably fall within the normal course of required study in the overall OLF development. Such areas include:

(a) OLF emergency operations (evacuation, rescue, etc.);

(b) Crew training -- verification of adequacy or inadequacy of ground training in simulators;

(c) Aerodynamic loading effects of OLF-type payloads on Saturn V launch vehicles;

(d) Various detailed design studies of OLF on-board mechanical systems, the basic MORL module extension system, elevator system, service umbilical tower, equipment and cargo handling mechanisms, etc.

More detailed discussions and recommendations regarding the research requirements of an OLF development are presented in the <u>Research and Technology Implications Report</u>, Volume III, of this final report of the OLF study.

9.0 REFERENCES

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